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THE HYDRAULIC CHARACTERISTICS OF BAFFLE-EQUIPPED FISHWAYS

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THE HYDRAULIC CHARACTERISTICS OF BAFFLE-EQUIPPED FISHWAYS

1. This brief report is a partial summary of the findings of research on baffle-equipped fishways that was conducted on a model system at the fish-farming facility in Pont Crouzet, in the **département** of the Tarn. The experimental setup consisted of two basins in which fish could be kept, connected by a glass-lined flume 0.30 m wide and 4.6 m long with a variable slope (ranging between 0 and over 20%).

2. Laboratory trials had previously demonstrated the basic principle underlying the concept of the baffle-equipped fishway, namely the creation of three-dimensional turbulence-generating obstacles (or "spinning jets") with a view to minimizing dead-water areas that contribute only slightly to energy dissipation. In plain English, the idea is to set up components of velocity in a direction other than the direction of the main flow of water.

3. While the number of possible solutions is theoretically infinite, in practice baffles with simple shapes are the only ones worth considering. The aim of the trials was to identify four or five types of baffle that could be adapted to the relevant features of most actual field conditions: changes in upstream water level conditions during the migration season, acceptable slope and discharge conditions within the fishway, and acceptable velocities in the fishway for the migratory species under consideration.

4. Subsequently, the investigators observed the swimming behaviour of the experimental fish (brown and rainbow trout, both adults and juveniles, were used) with each type of baffle. As a result of the observations made at this stage, some baffle designs were modified or even scrapped altogether. Experience showed that solutions which were ideal from a hydraulic standpoint were not always equally desirable in terms of fish production, and vice versa.

5. The hydraulic characteristics of the most satisfactory configurations were determined: mean discharge and depth-of-flow values in the fishway were measured for various slopes and upstream water conditions. A current meter was used for velocity logging. Observation of the movement of lengths of yarn tied to metal rods or grids placed in the flowing water was used as a means of visualizing the structure of the flow and the direction of eddies and subcurrents.

6. The results of the trials have been plotted nondimensionally, so that they can be applied to fishways of any size. The main parameters are:

W : width of fishway (in metres)

t : thickness of baffle (in metres)

L : longitudinal spacing of baffles (in metres)

a,A,B,C,D,H : dimensions characterizing the shape and placement of baffles (in metres)

Q : fishway discharge (in m^3/s)

h_u : upstream load (in metres) above the fishway feed-in level (which is the level found either at the fishway's upstream apron or at the tip or the lower lip of the leading baffle, depending on the configuration being considered).

h : mean depth of flow in the fishway.

The velocity log readings are the only ones that have been left in dimensional form. To obtain velocity values for a prototype fishway of width W, it is only necessary to multiply the velocity values (in m/s) shown on the graphs by 1.83 $\sqrt{W}$ (Froude number).

7. The several types of baffle whose hydraulic characteristics are appended to this report are:

I High-activity bottom baffles (type A)

II Flat baffles

III Wing baffles

IV "Fatou" baffles

V Lateral V baffles

VI High-activity side baffles (type A)

VII High-activity side baffles (type A) associated with high-activity bottom baffles (type B)

8. Variations in the relationship between discharge and upstream load for different slope values

This relationship is a useful guide to "setting" the fishway, i.e. determining its discharge on the basis of the position of the leading (furthest upstream) baffle--or the elevation of the upstream apron--in relation to the upstream water level.

The relationship between discharge and upstream load depends to some extent on lead-in conditions, i.e. whether the side walls are rounded or not and whether a number of baffles have been placed horizontally for the purpose of "baiting" the fishway.

In practice, observed discharge values will be meaningful only if the lead-in conditions are not markedly different from those used in our trials, i.e. the monitoring site should be located abreast of the first baffle rather than further upstream. In particular, the fishway's upstream apron should always be set lower than the elevation of the leading baffle: it is desirable to avoid jet formation, with the associated risk of lag in the "baiting" of the fishway.

By way of illustration, the type of fishway equipped with high-activity baffles was investigated with three different sets of upstream lead-in conditions (see figures). The addition of five baffles upstream (with and without side walls) reduced the discharge by factors of 21% and 32% respectively relative to the initial configuration for an upstream level such as $h_u/a = 4$.

9. Relationship between discharge and depth of flow

Relationships between discharge and depth of flow were found to depend only on baffle configuration and slope. Discharge values in fishways equipped with baffles increased with slope, albeit less than might have been inferred from conventional load-loss formulas.

For all types of baffle considered except type A high-activity bottom baffles and Fatou baffles, the curves are characterized by a more or less pronounced kink at the point of the "baiting" of the fishway, i.e. the point where secondary currents appeared; this phenomenon is reflected in an abrupt increase in depth of flow in the fishway as a result of a small increase in the upstream level.

10. Minimum operating conditions

- In the case of high-activity bottom baffles (type A) and Fatou baffles, it was found that the depth of flow must be adequate to allow the fish to swim through (in the case of salmon, h > approximately 0.30 m).

- In the case of flat baffles and wing baffles, it appeared preferable for the h/W ratio to be located above the kink (h/W > 0.50).

- In the case of side baffles (high-activity type or V type), it proved essential for an entire strip to be immersed (for purposes of baiting the fishway), and this means that h/5a > 1.

- In the case of high-activity side baffles (type A) associated with high-activity bottom baffles (type B), the baiting condition was h/5a > 0.80. We found, however, that because of the presence of bottom baffles, the fishway could actually be operated satisfactorily with a lower depth of flow in it, provided the depth was sufficient to allow the fish to swim through.

11. Velocity logging in fishways (see figures)

(a) <u>High-activity bottom baffles (type A)</u>

A high-velocity central stream (following the V-tips of the baffles) flanked by two low-velocity zones.

(b) Flat baffles and wing baffles

The lowest velocities were found in the lower part of the fishway (near the tip in the case of flat baffles, and near the apron in the case of wing baffles). These velocity values increased only slightly with slope and discharge in the fishway. The highest velocities were observable at the surface; these values increased with slope and discharge in the fishway.

(c) Fatou baffles

The velocity profiles were strongly flattened, maximum speeds being logged along the bottom of the fishway. Velocity values increased with slope and discharge.

(d) Side baffles: V-shaped, high-activity (type A), and high-activity (type A) associated with high-activity bottom baffles (type B)

Maximum velocities were found, broadly speaking, at the tip of each section, while minimum velocities were observed along the bottom and near the strips separating the several sections.

Maximum velocities increased with slope, whereas minimum velocities remained relatively constant.

Velocities along the bottom, from the point of "baiting" on in, were generally not sensitive to fluctuations in discharge.

Bottom baffles (type B) were found to reduce velocity values in the entire lower section of the fishway.

12. Fish behaviour

(a) We found that drawing objective conclusions from the observation of fiwh swimming activity in a fishway was a very delicate business. While data obtained in this way did provide grounds for discarding some baffle configurations, the fact remains that extreme caution had to be used in comparing the effectiveness of any two different types of baffle, since:

- fish behaviour varied not only from day to day but from hour to hour;
- it was difficult to allow for the influence of the glass-lined wall and the presence of an observer;
- it was difficult to use the same batch of fish--especially where the fish in question were wild trout--for a number of trials (the trout could not be fed, they were hard to handle, our downstream basin was inconveniently small, and so on).

Genuinely objective findings, consisting of data suitable for use as a basis for comparing the effectiveness of two or more different types of baffle, could have been arrived at only by means of a statistical study comprising a substantial number of trials for each configuration, and even then only provided the trials had been adequately distributed over time and had involved different batches of fish, which, however, would have had to include specimens from all size classes.

Even had such data been obtained, it still would not have been easy to use effectiveness as determined with a reduced-scale model as a basis for construction of a prototype, inasmuch as it is difficult to establish similarity criteria for fish swimming capabilities that are as rigorous as hydraulic similarity criteria.

(b) None the less, our observations did demonstrate the following:

- Fish tended to seek out low-velocity zones.

In the trials with Fatou baffles, the fish were found to be distributed throughout the entire water layer in the fishway owing to the fact that the velocity profile was relatively flat.

- Fish appeared to make progress much more easily where the low-velocity zone was located in the immediate vicinity of a surface with no baffles on it, i.e. side walls in the case of high-activity baffles, or the bottom of the fishway in the case of wing baffles, V-shaped or high-activity side baffles.

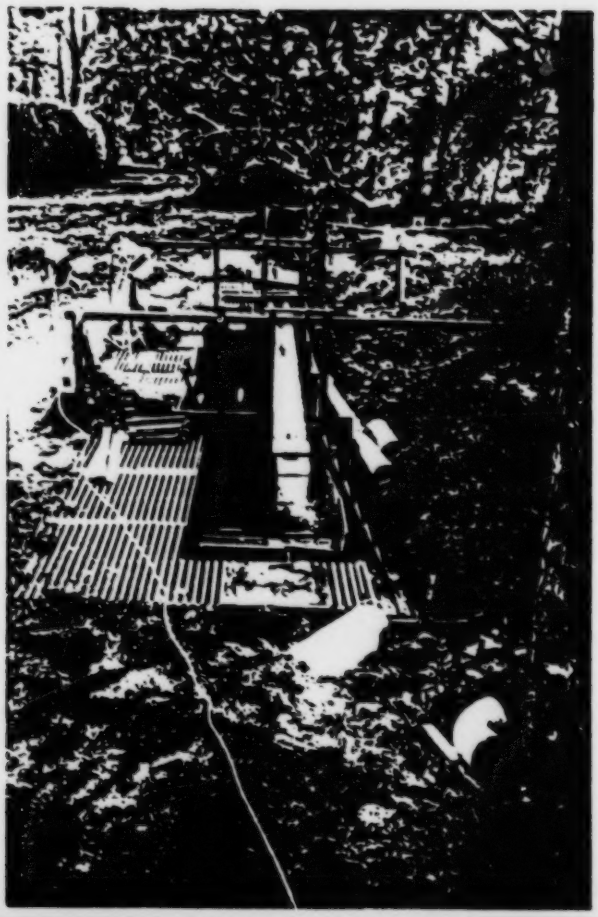
- There appeared to be a problem of relative scale between fish size and the magnitude of the jets in the fishway, a feature dictated by the spacing of the baffles and hence the size of the fishway: the larger the fish in relation to the eddies, the more easily it appeared to be able to swim.

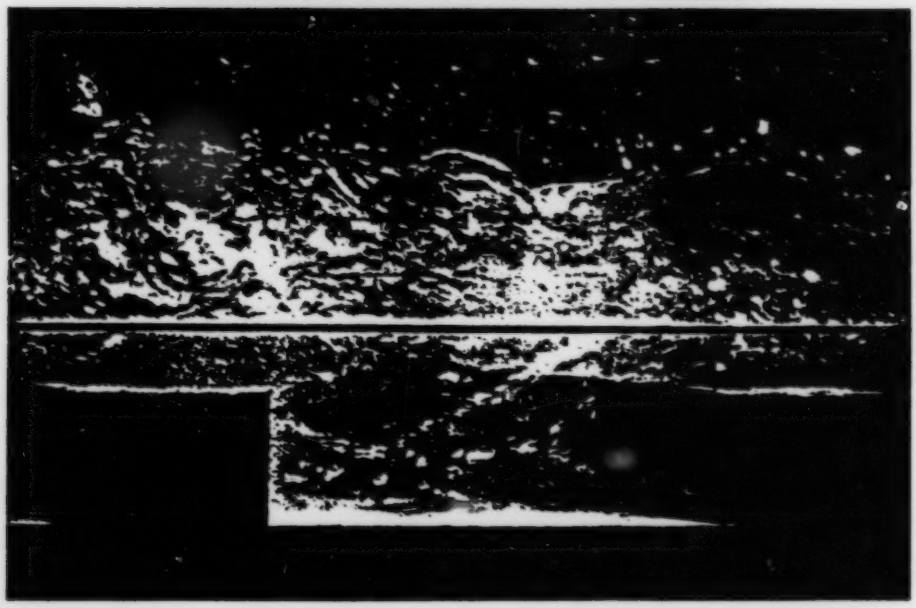
Fish were frequently observed swimming against secondary currents and consequently colliding with the side walls or bottom of the flume (in the case of high-activity baffles or flat baffles).

Some specimens that were initially disoriented by the flow configuration

in the fishway appeared subsequently to adapt and learned to navigate their way through.

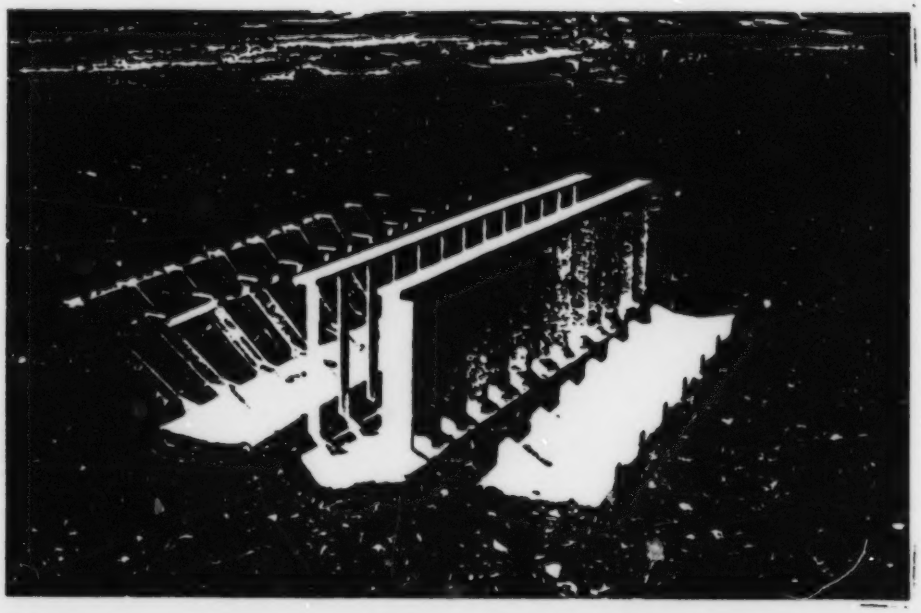
As a rule, the fish spent some time in the upstream part of the fishway, i.e. in the region where the change in flow structure occurs. Accordingly, it would seem to be desirable to ensure that the transition between upstream conditions and fishway flow is not too abrupt; in particular, the formation of a high-speed jet upstream of the first baffle should be avoided.

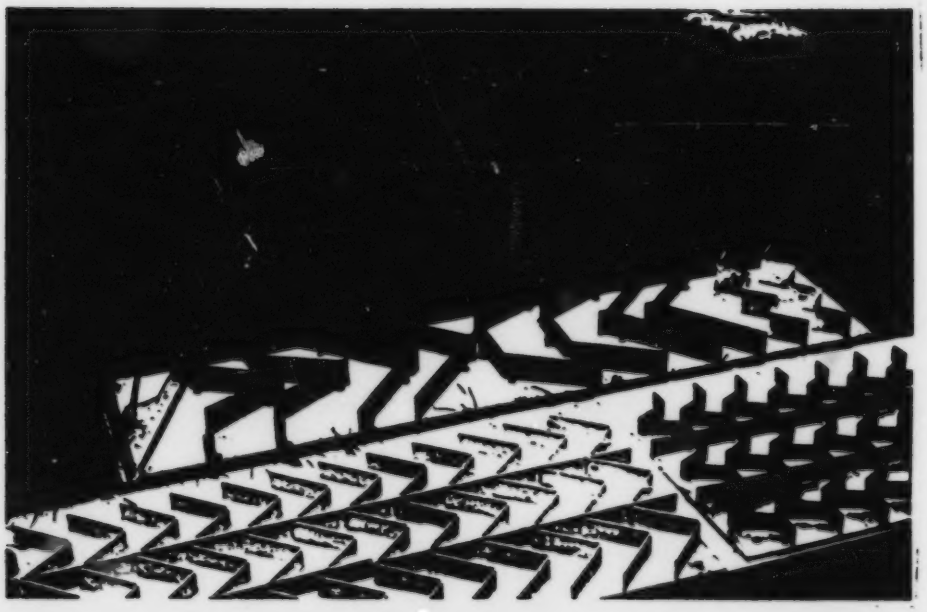




Experimental facility in Pont Crouzet, in the département of the Tarn

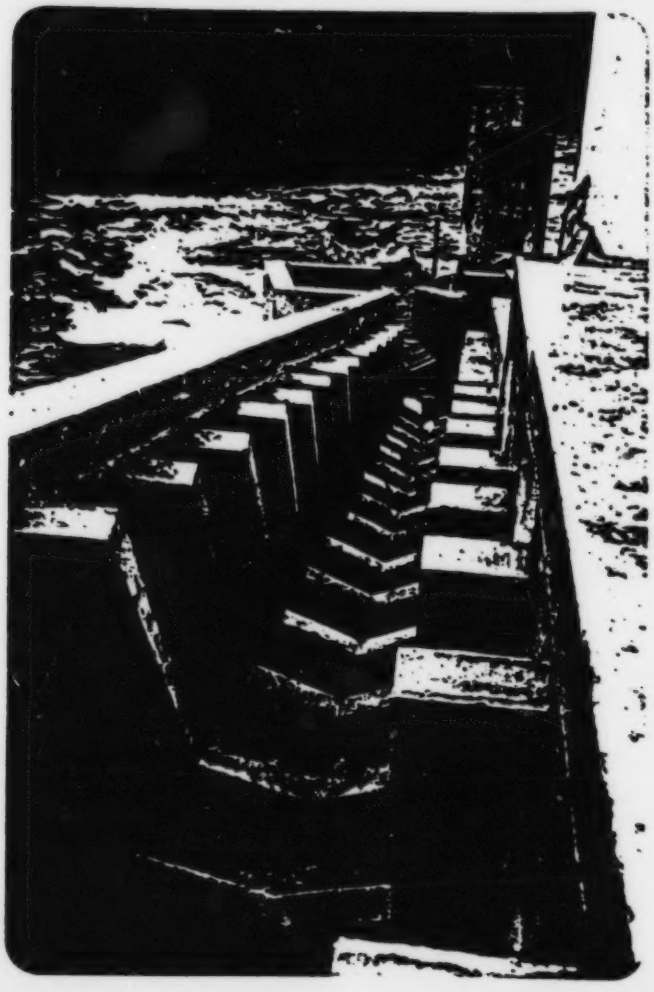
Flow above thick-construction V-shaped baffles.





Experimental facility in Pont Crouzet

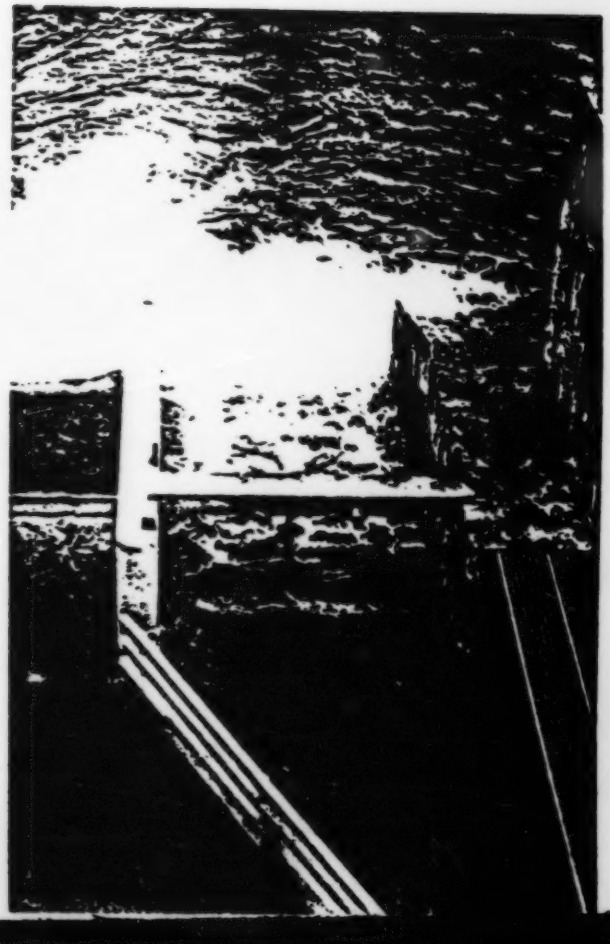
Different types of baffles subjected to testing with a model fishway.



Fishway equipped with flat baffles on the river known as the Gave d'Ossau, in the département of Pyrénées-Atlantiques.

Combined fishway and canoe bypass on the Aveyron River.

Fishway equipped with high-activity bottom baffles on the Allier River.



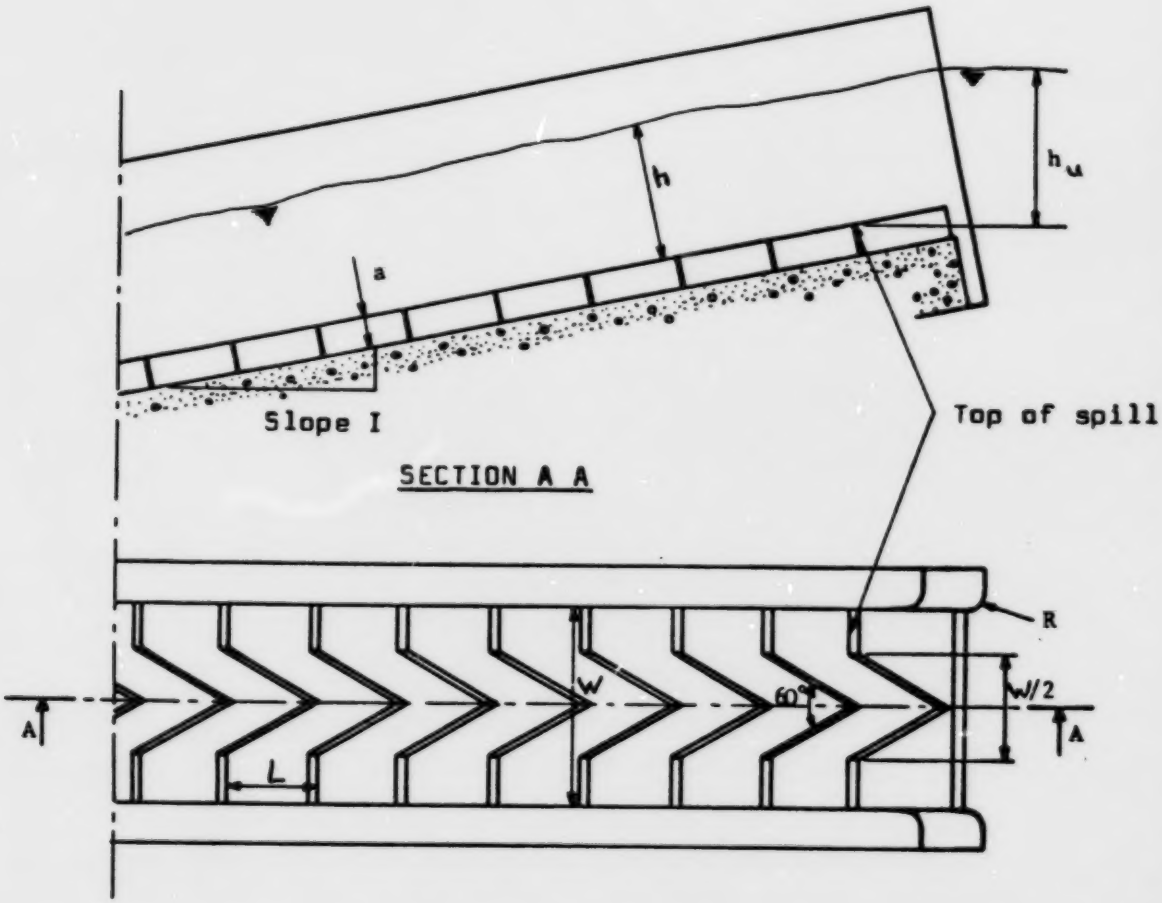
BAFFLE-EQUIPPED FISHWAYS

CEMAGREF WQFAD

October 1981

FISHWAY EQUIPPED WITH HIGH-ACTIVITY BOTTOM BAFFLES

TYPE A



OVERHEAD VIEW

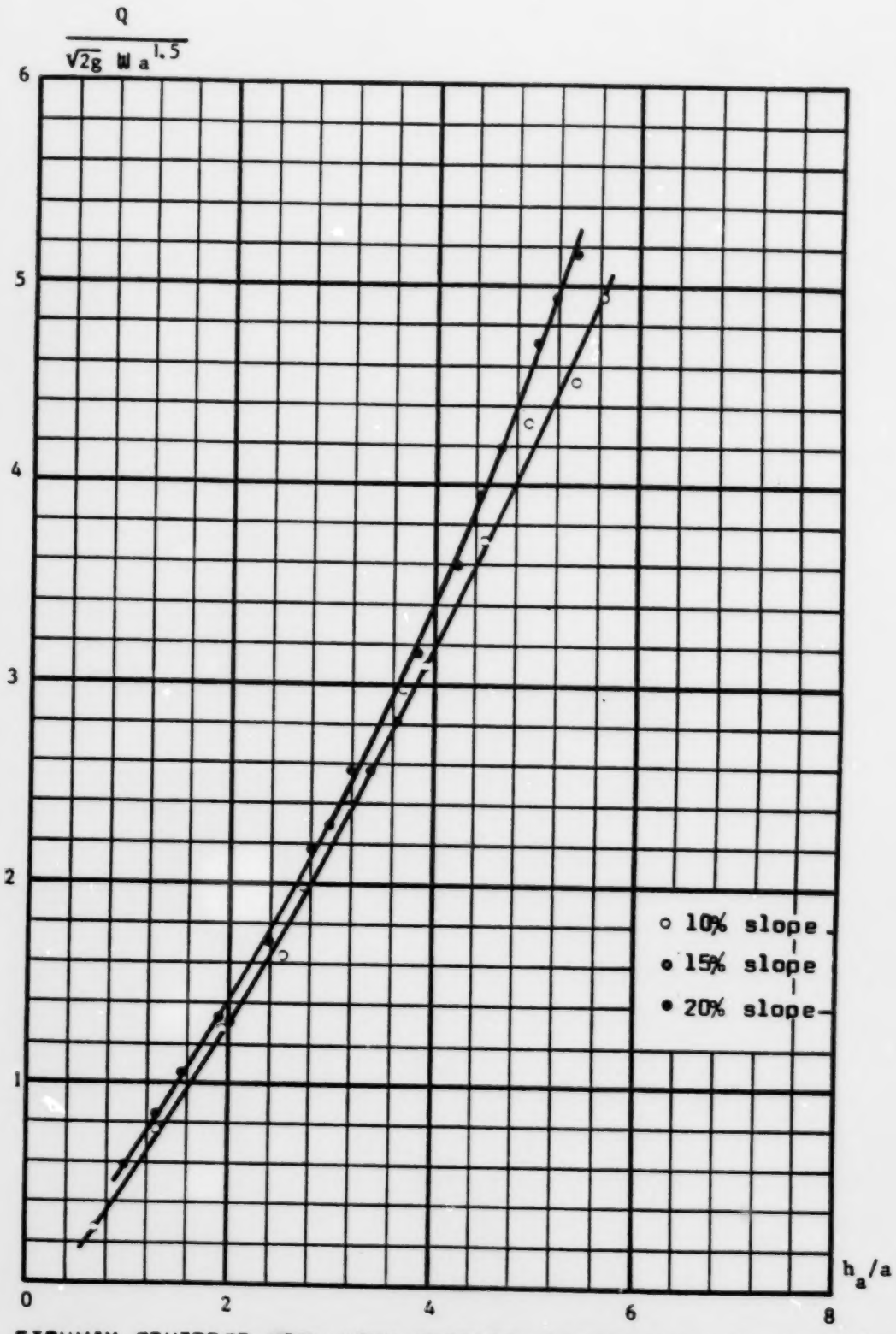
W = 6 a

L = 2,60 a

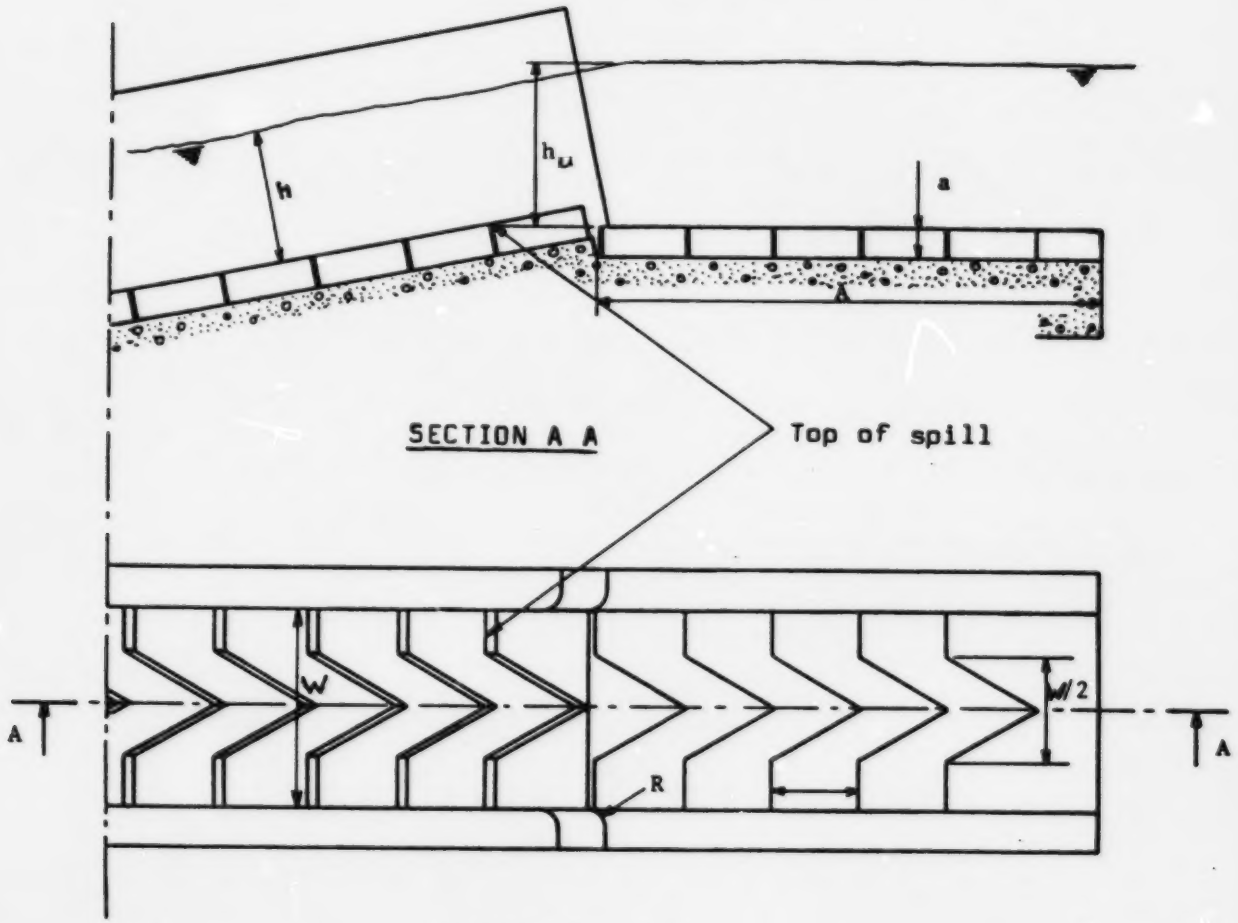
R = 0,90 a

CHARACTERISTIC PARAMETERS OF A FISHWAY EQUIPPED WITH HIGH-ACTIVITY BOTTOM BAFFLES (TYPE A)

(Lateral zones of low velocity. The lead-in conditions represented are the same as those used in the trials - Lead-in I)



FISHWAY EQUIPPED WITH HIGH-ACTIVITY BOTTOM BAFFLES, TYPE A
Relationships among discharge, upstream load and slope



OVERHEAD VIEW

W = 6 a

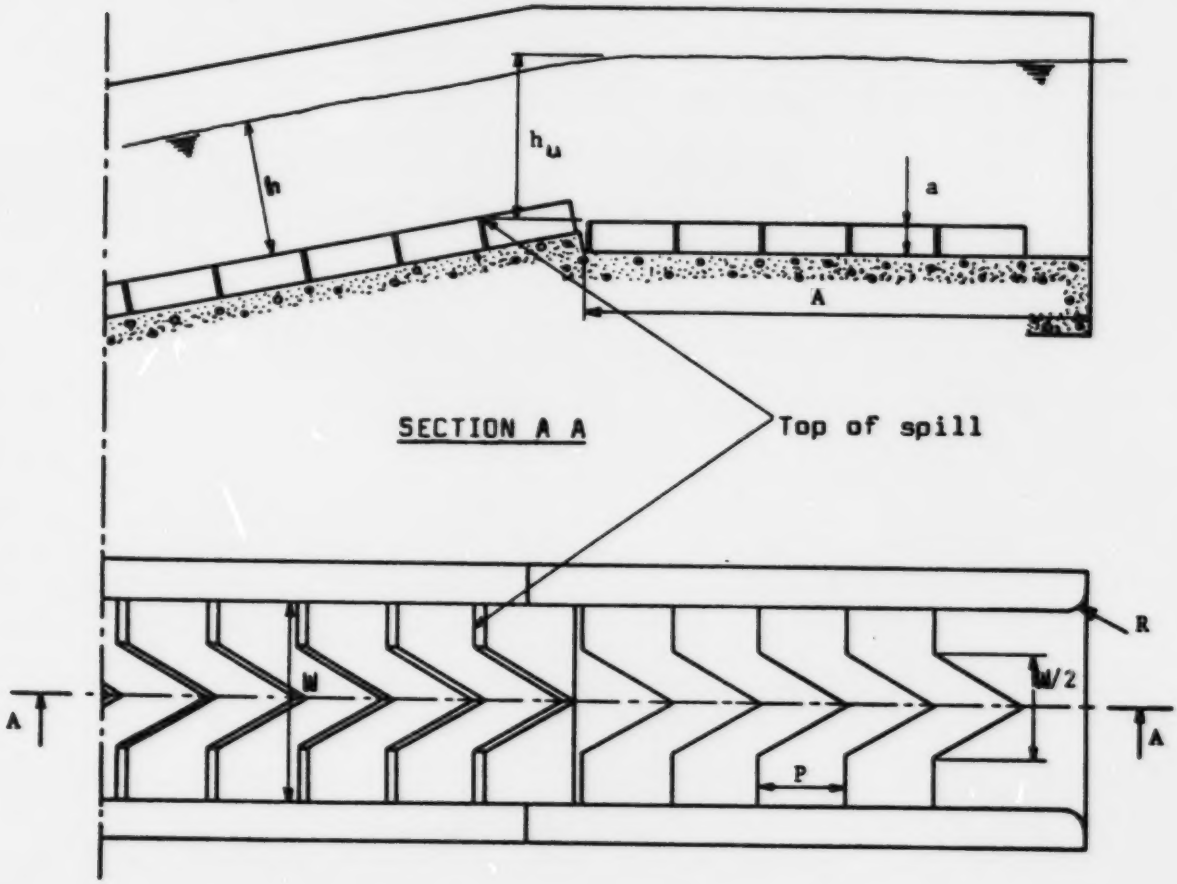
L = 2,60 a

R = 0,90 a

A = 15 a

CHARACTERISTIC PARAMETERS OF A FISHWAY EQUIPPED WITH HIGH-ACTIVITY BOTTOM BAFFLES, TYPE A, WITH AN UPSTREAM HORIZONTAL EXTENSION CONTAINING FIVE BAFFLES

(The lead-in conditions represented are the same as those used in the trials - Lead-in II)



OVERHEAD VIEW

W = 6 a

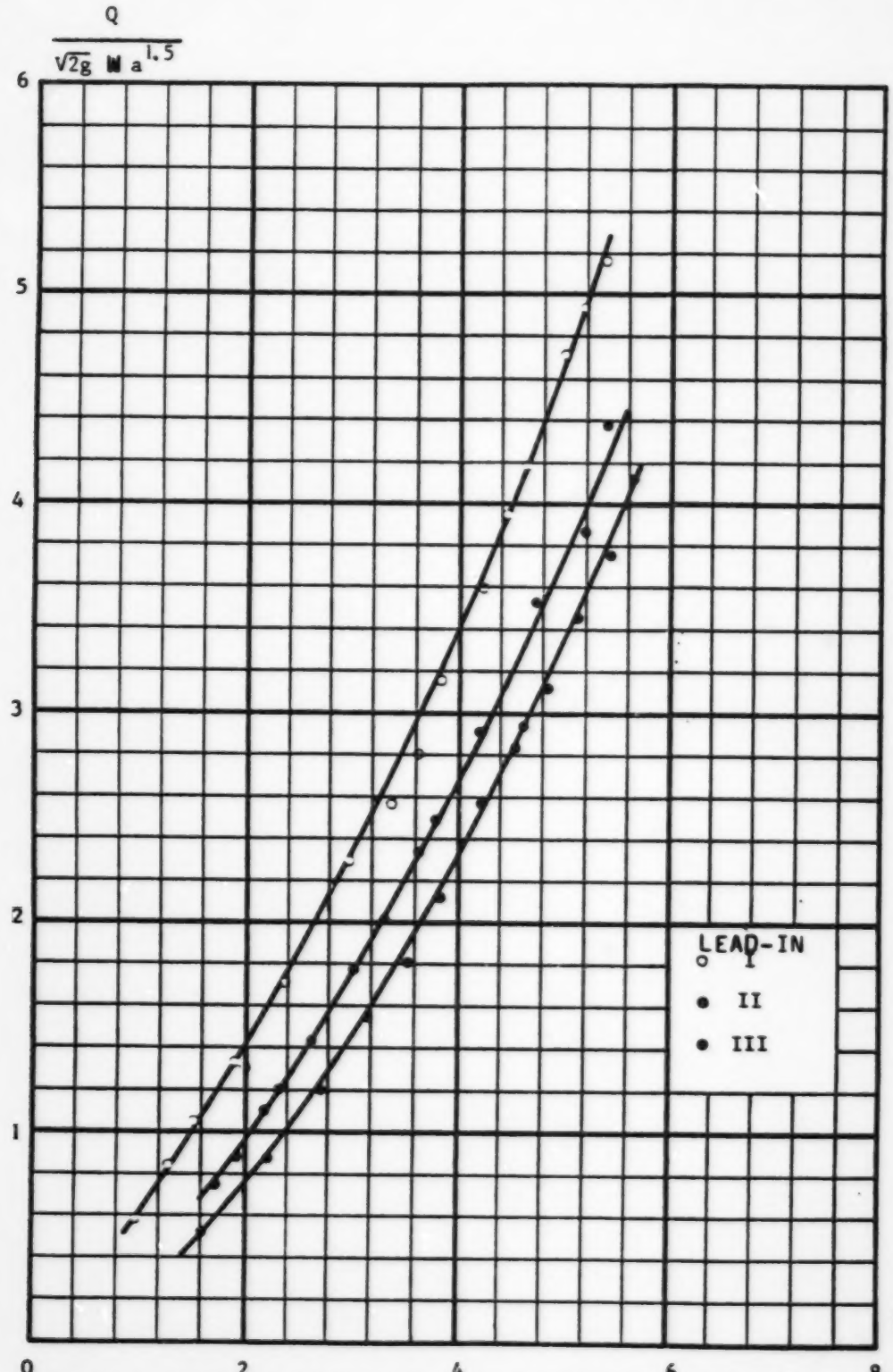
L = 2,60 a

R = 0,90 a

A = 15 a

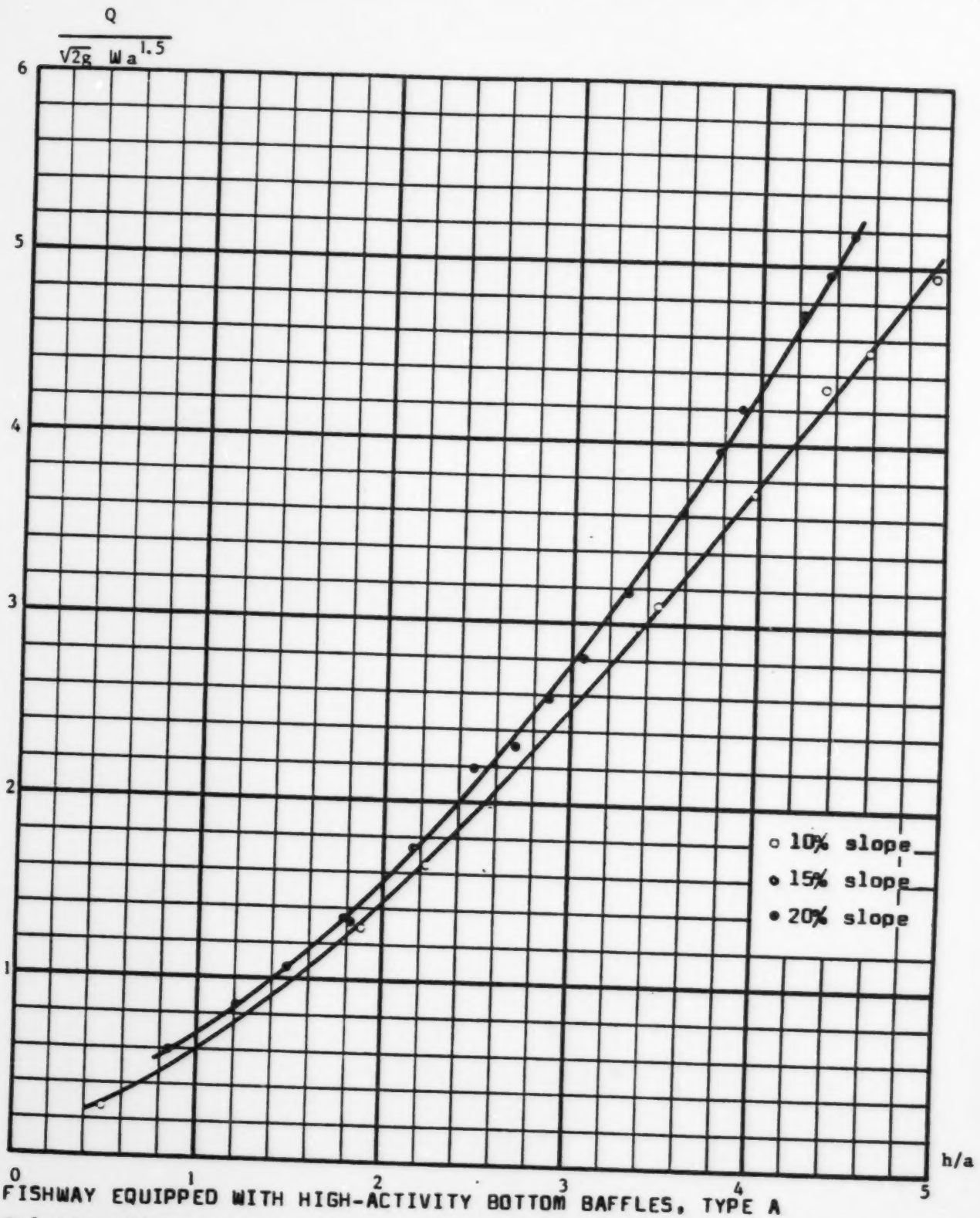
CHARACTERISTIC PARAMETERS OF A FISHWAY EQUIPPED WITH HIGH-ACTIVITY BOTTOM BAFFLES (TYPE A) WITH AN UPSTREAM HORIZONTAL FLUME CONTAINING FIVE BAFFLES

(The lead-in conditions represented are the same as those used in the trials - Lead-in III)



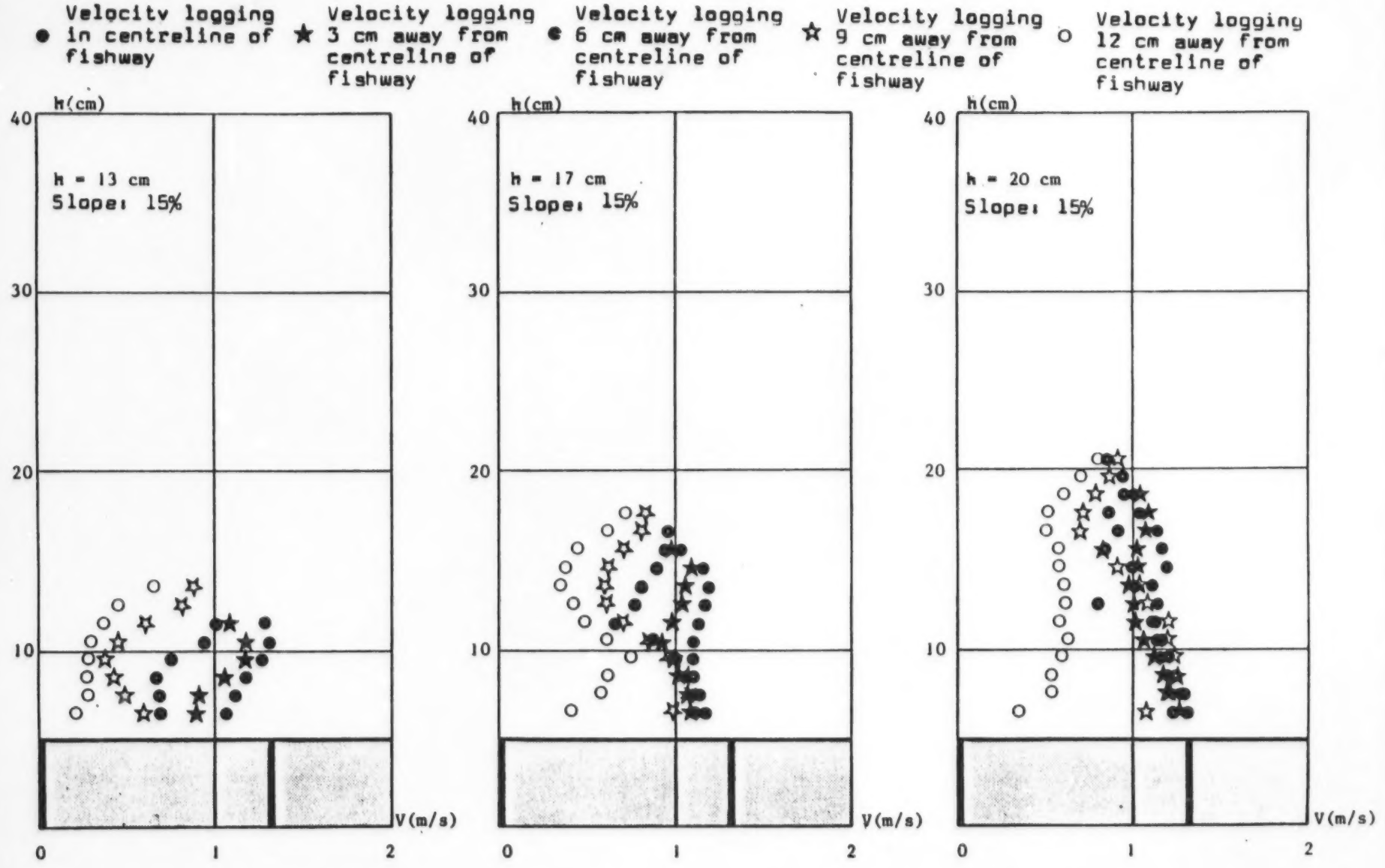
FISHWAY EQUIPPED WITH HIGH-ACTIVITY BOTTOM BAFFLES (TYPE A)

Relationships among discharge, upstream load and type of lead-in



FISHWAY EQUIPPED WITH HIGH-ACTIVITY BOTTOM BAFFLES, TYPE A

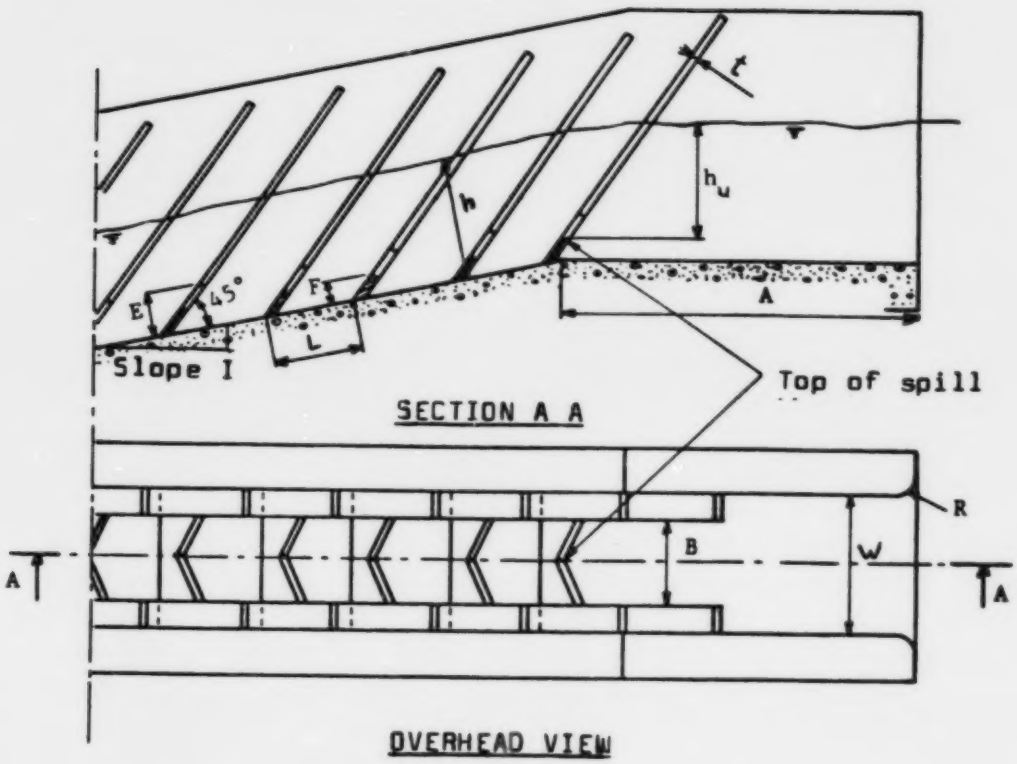
Relationships among discharge, depth of flow and slope

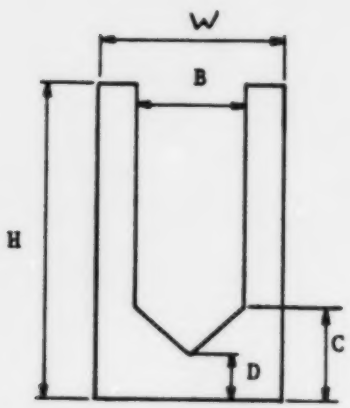


FISHWAY EQUIPPED WITH HIGH-ACTIVITY BOTTOM BAFFLES, TYPE A (width (W) = 30 cm)

Changes in velocity plotted against depth of flow

FISHWAY EQUIPPED WITH FLAT BAFFLES

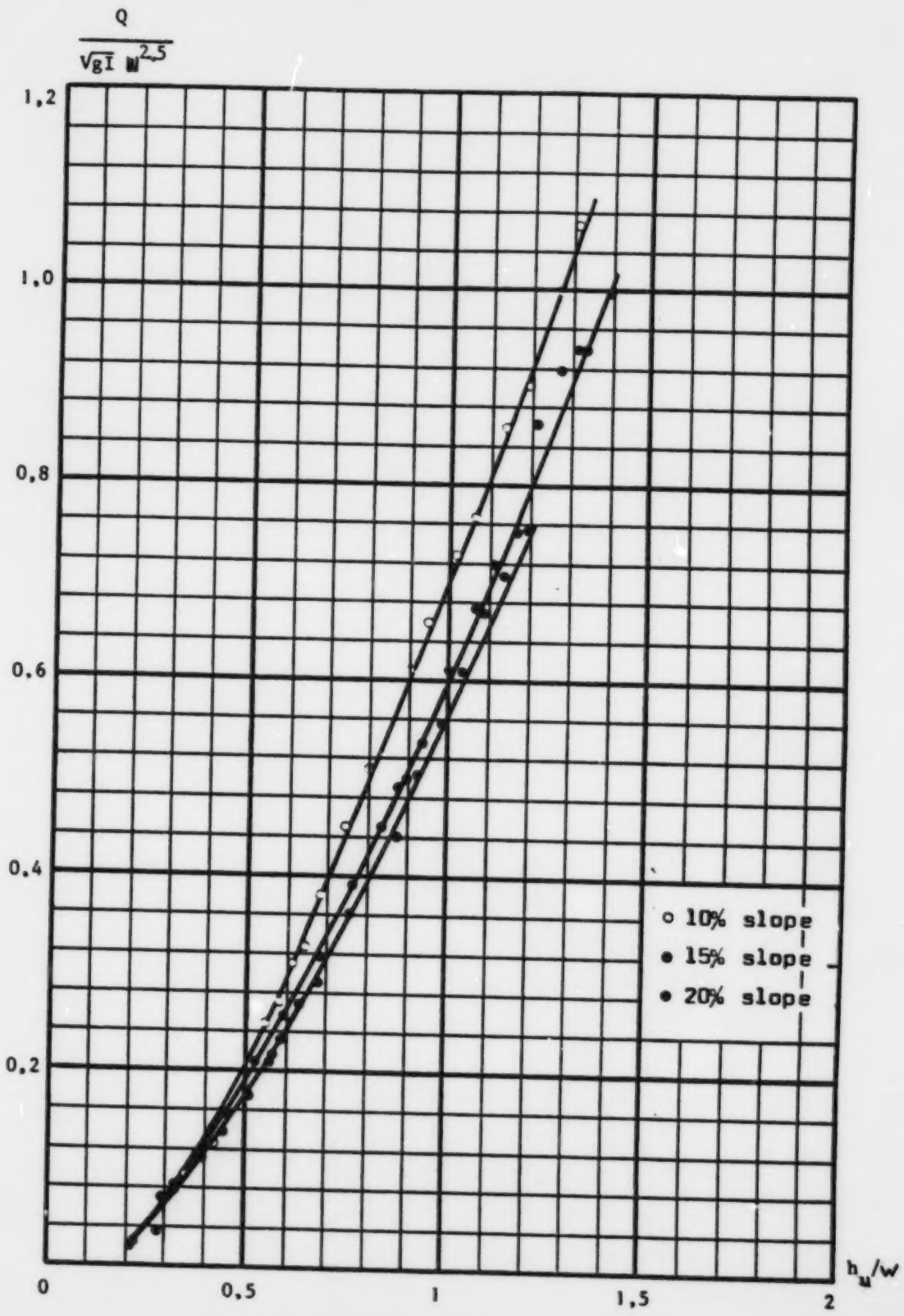




A = 2,50 W
B = 0,583 W
C = 0,472 W
D = 0,236 W
E = W/3
F = W/6
H = 2,20 W
L = 2/3 W
R = 0,150 W
t = 1/30 W

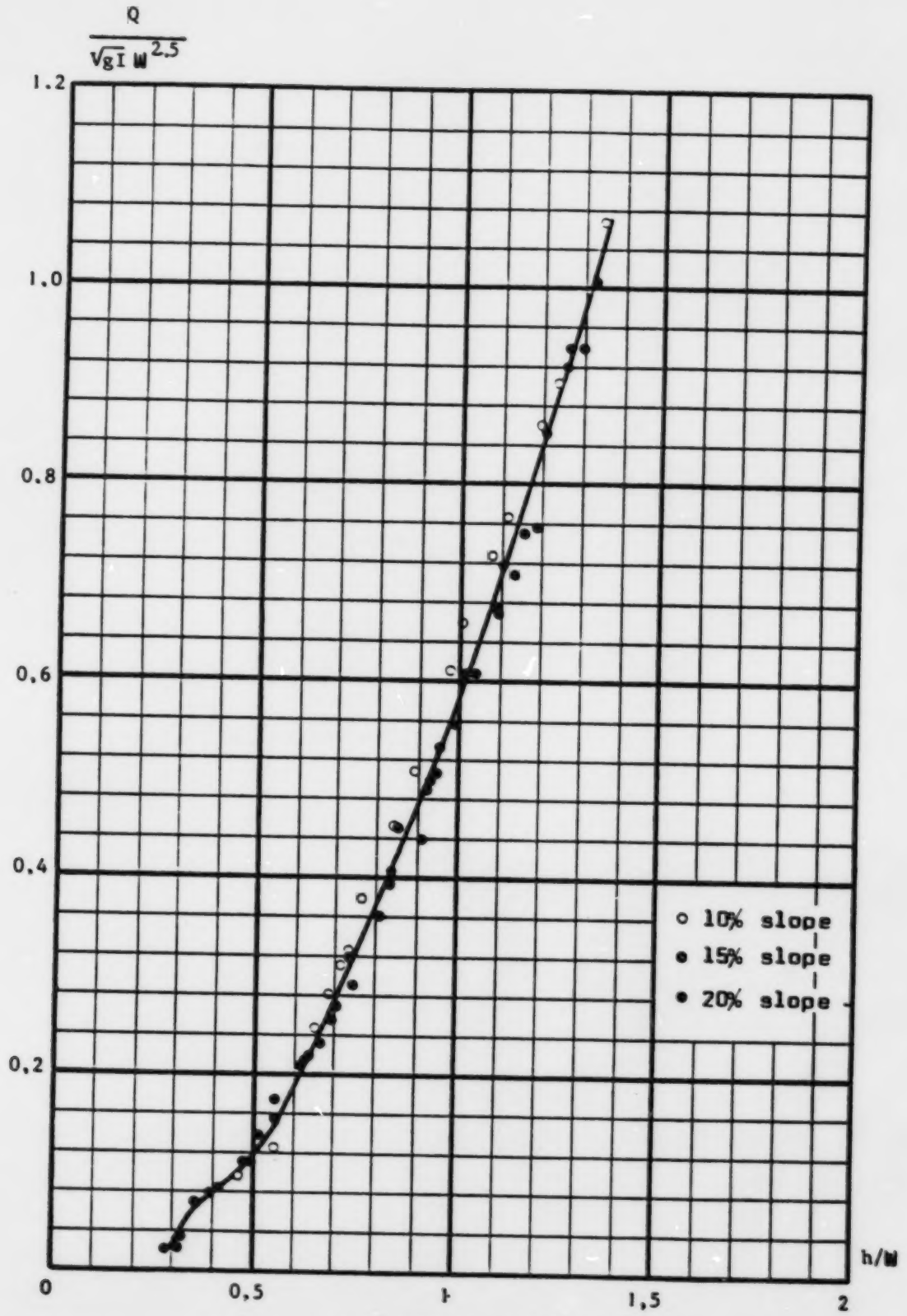
CHARACTERISTIC PARAMETERS OF A FISHWAY EQUIPPED WITH FLAT BAFFLES

(The lead-in conditions represented are the same as those used in the trials)



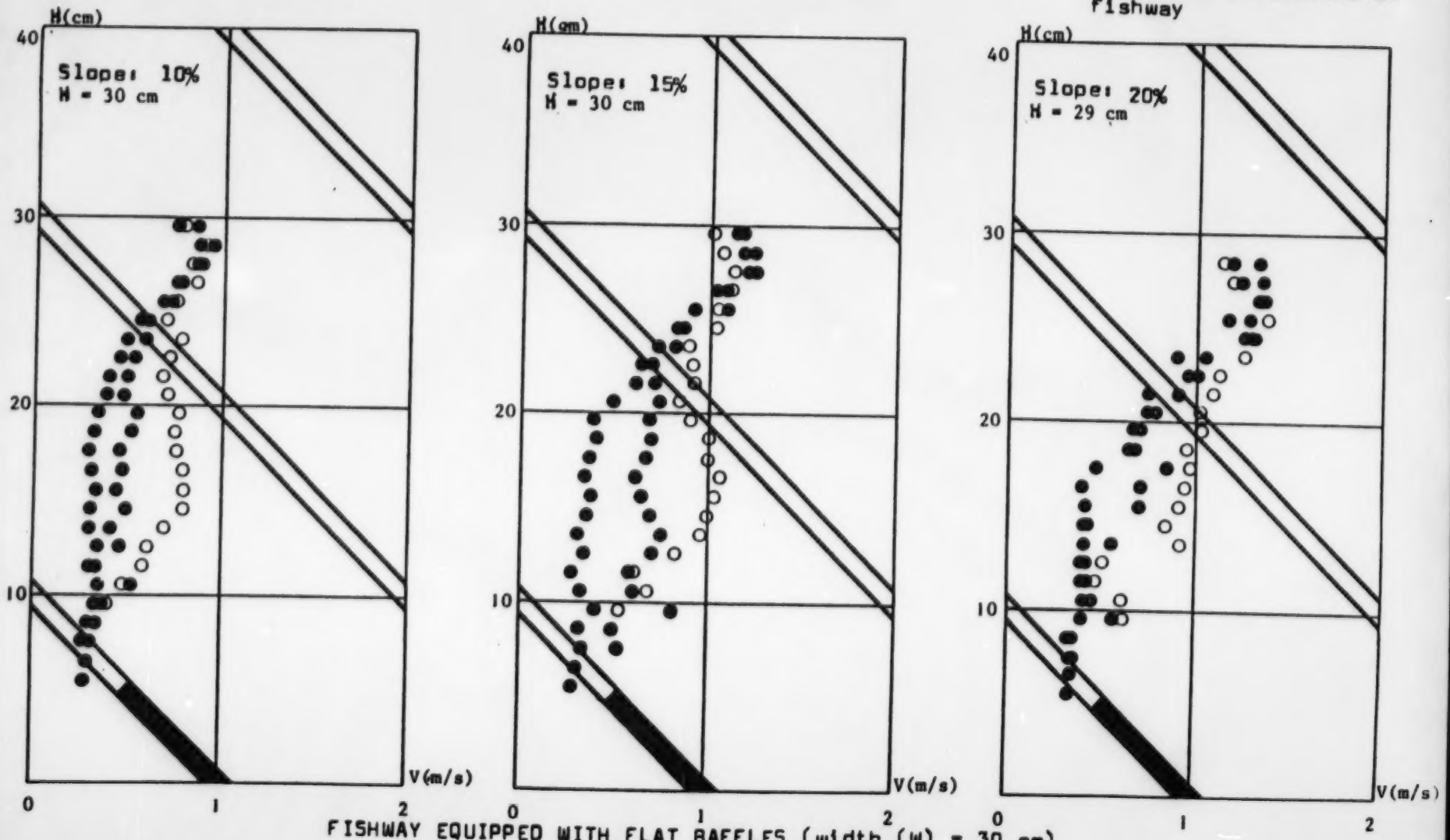
FISHWAY EQUIPPED WITH FLAT BAFFLES

Relationships among discharge, upstream load and slope



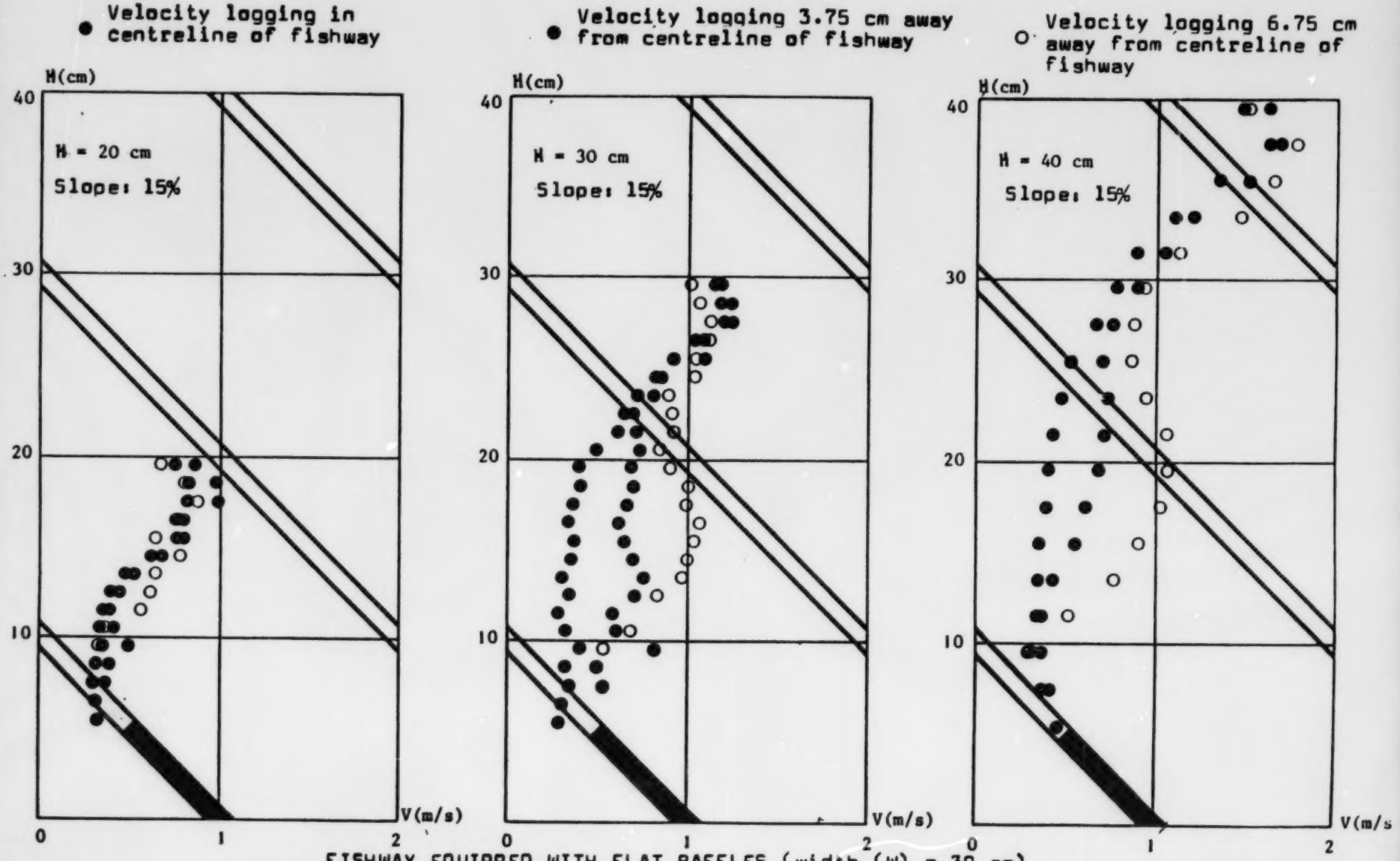
FISHWAY EQUIPPED WITH FLAT BAFFLES

Relationship between discharge and depth of flow in fishway



FISHWAY EQUIPPED WITH FLAT BAFFLES (width (W) = 30 cm)

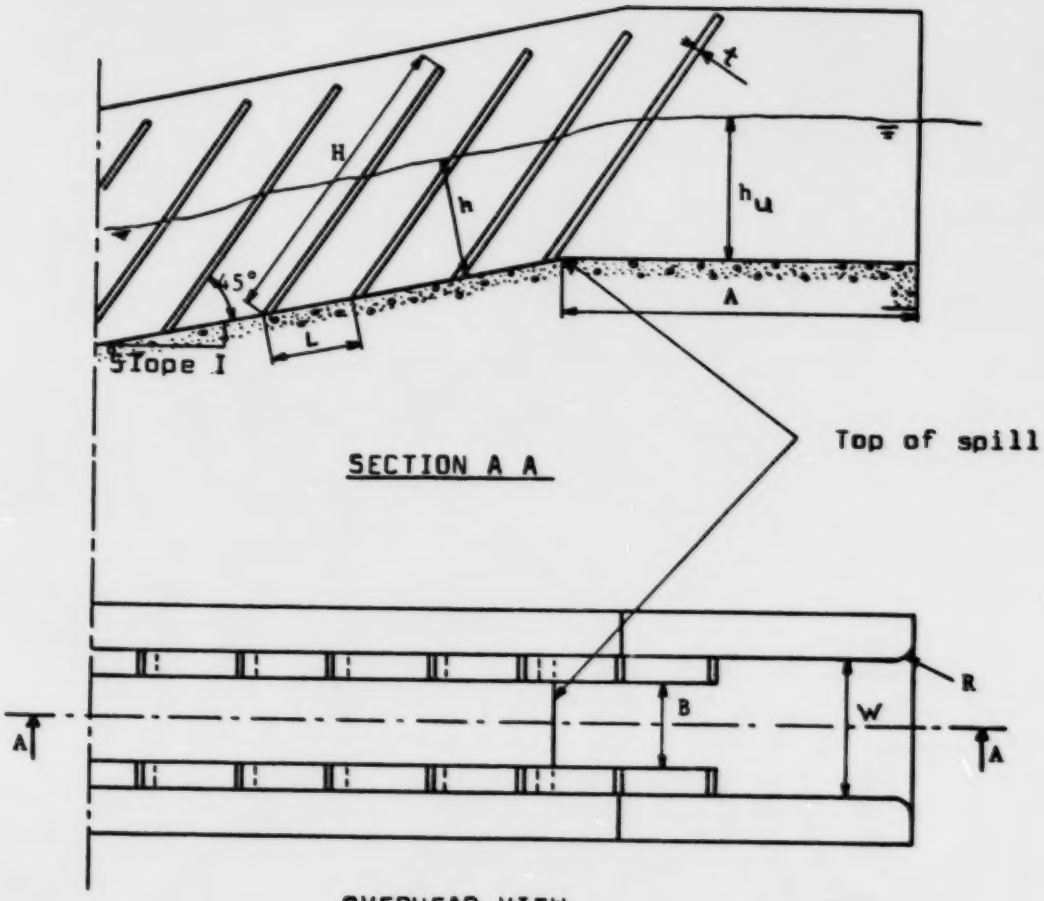
Changes in velocity plotted against slope



FISHWAY EQUIPPED WITH FLAT BAFFLES (width (W) = 30 cm)

Changes in velocity plotted against depth of flow

FISHWAY EQUIPPED WITH WING BAFFLES

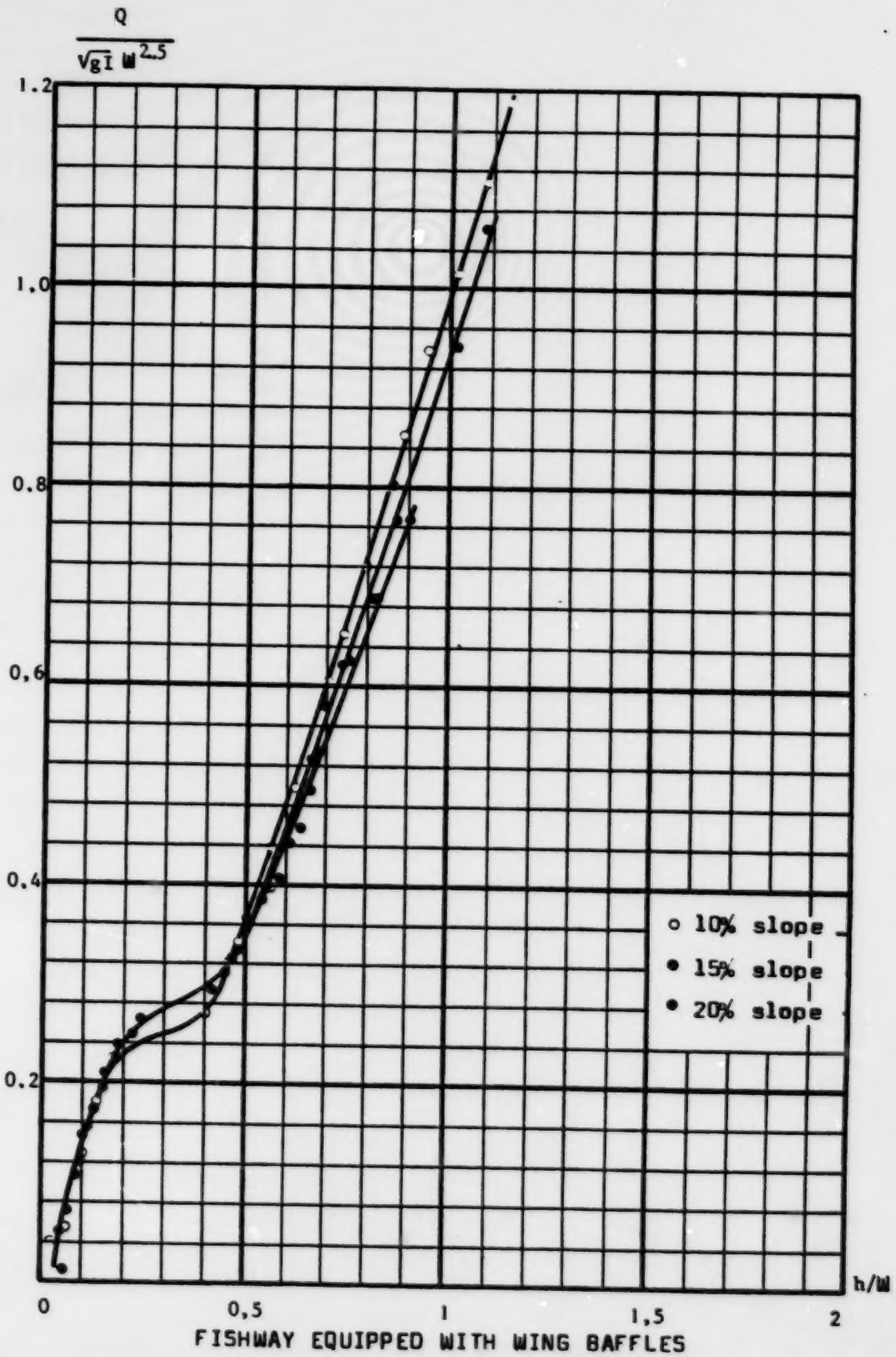


OVERHEAD VIEW

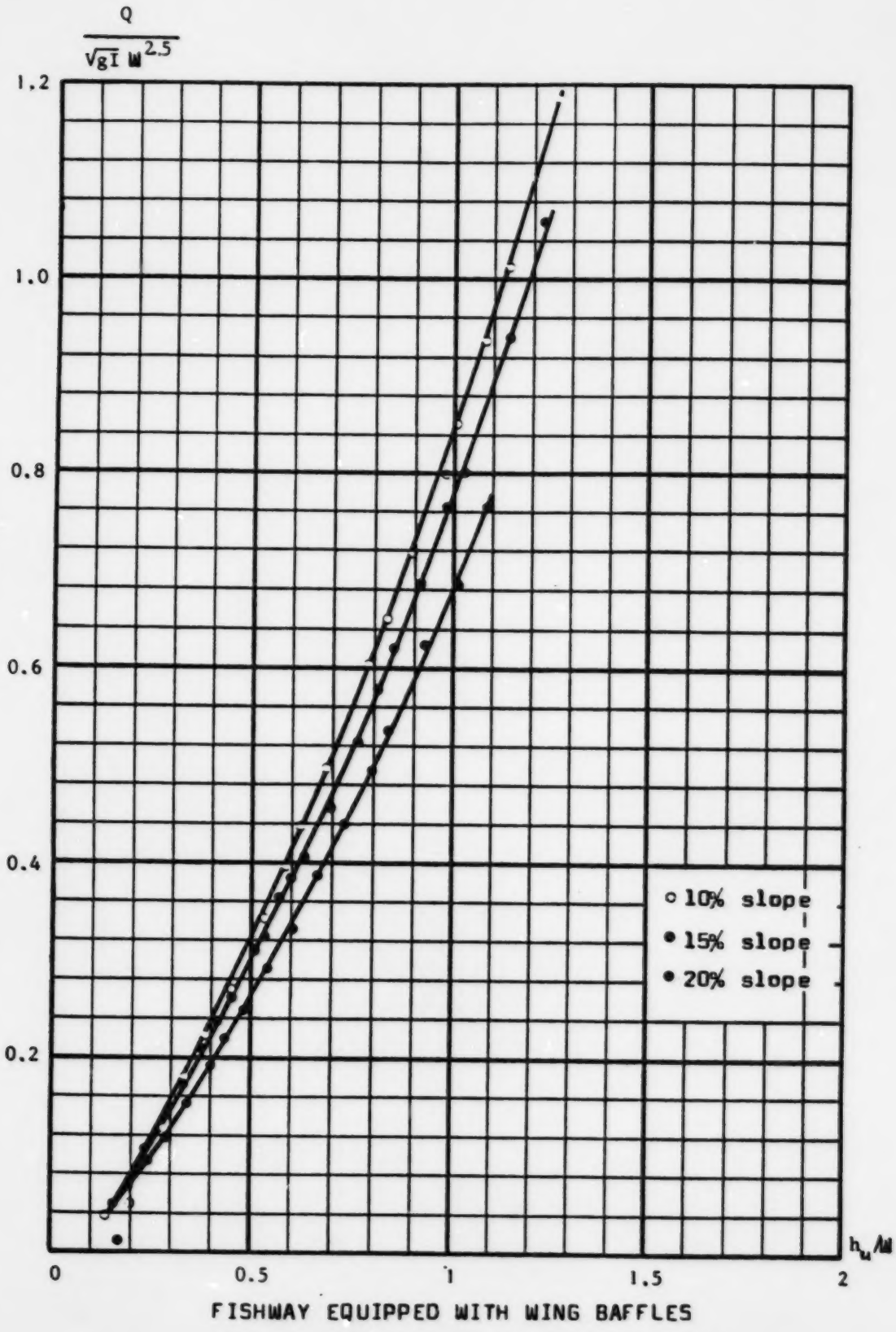
A = 2,5 W	H = 2,2 W
B = 0,583 W	R = 0,150 W
L = 2/3 W	t = 1/30 W

CHARACTERISTIC PARAMETERS OF A FISHWAY EQUIPPED WITH WING BAFFLES

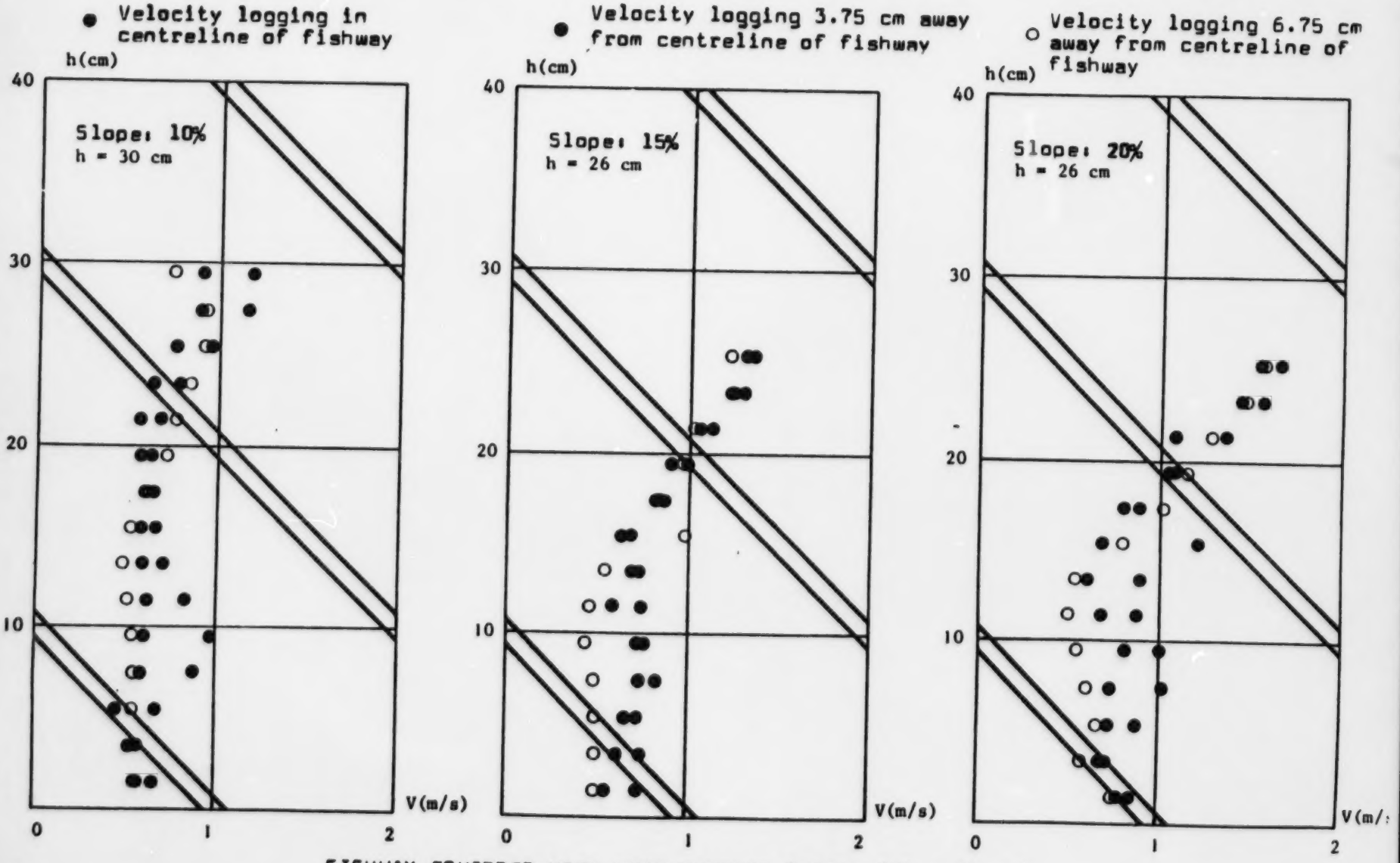
(The lead-in conditions represented are the same as those used in the trials)



Relationships among discharge, depth of flow and slope



Relationships among discharge, upstream load and slope



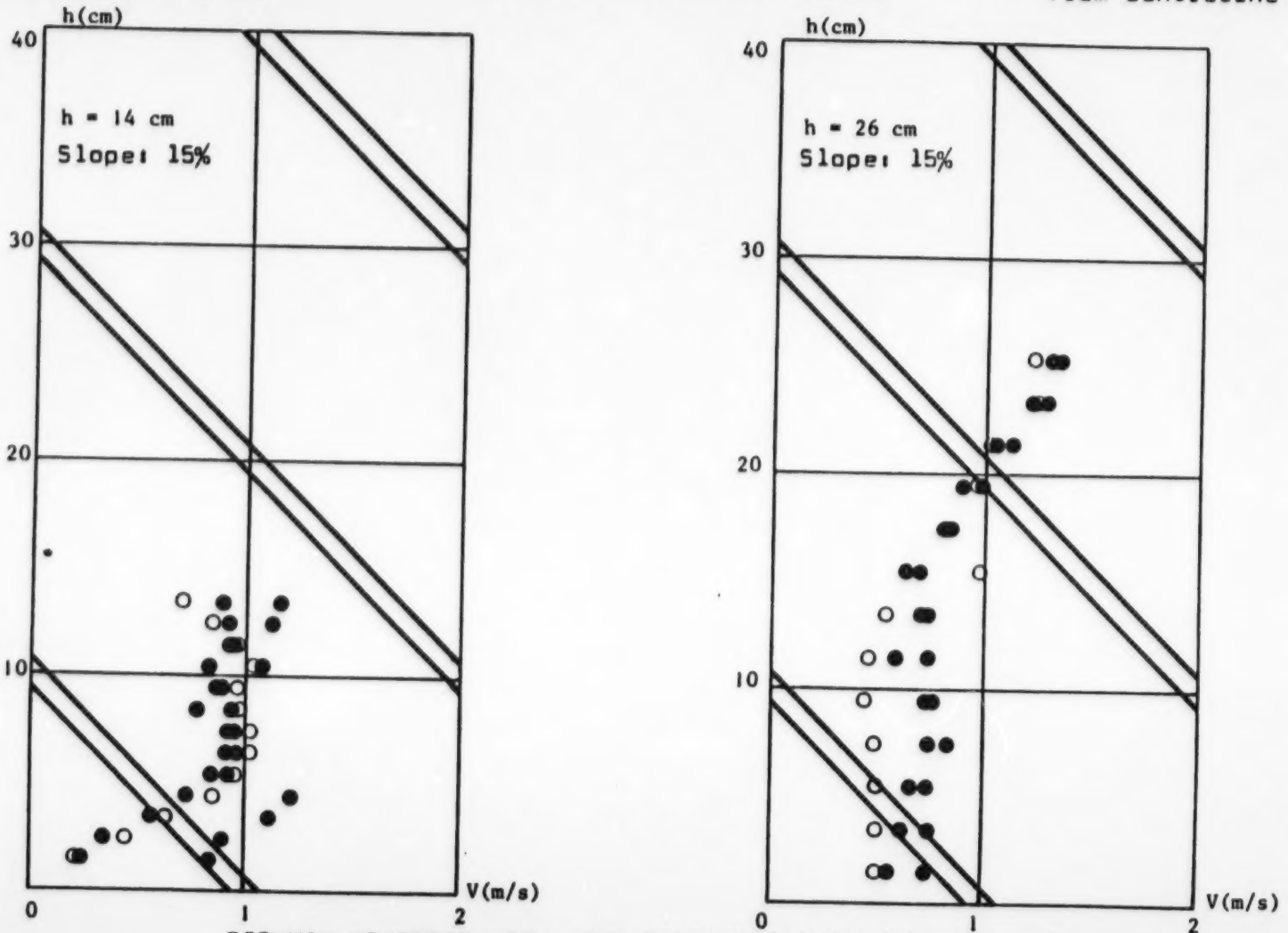
FISHWAY EQUIPPED WITH WING BAFFLES (width (W) = 30 cm)

Changes in velocity plotted against slope

● Velocity logging in centreline of fishway

● Velocity logging 3.75 cm away from centreline of fishway

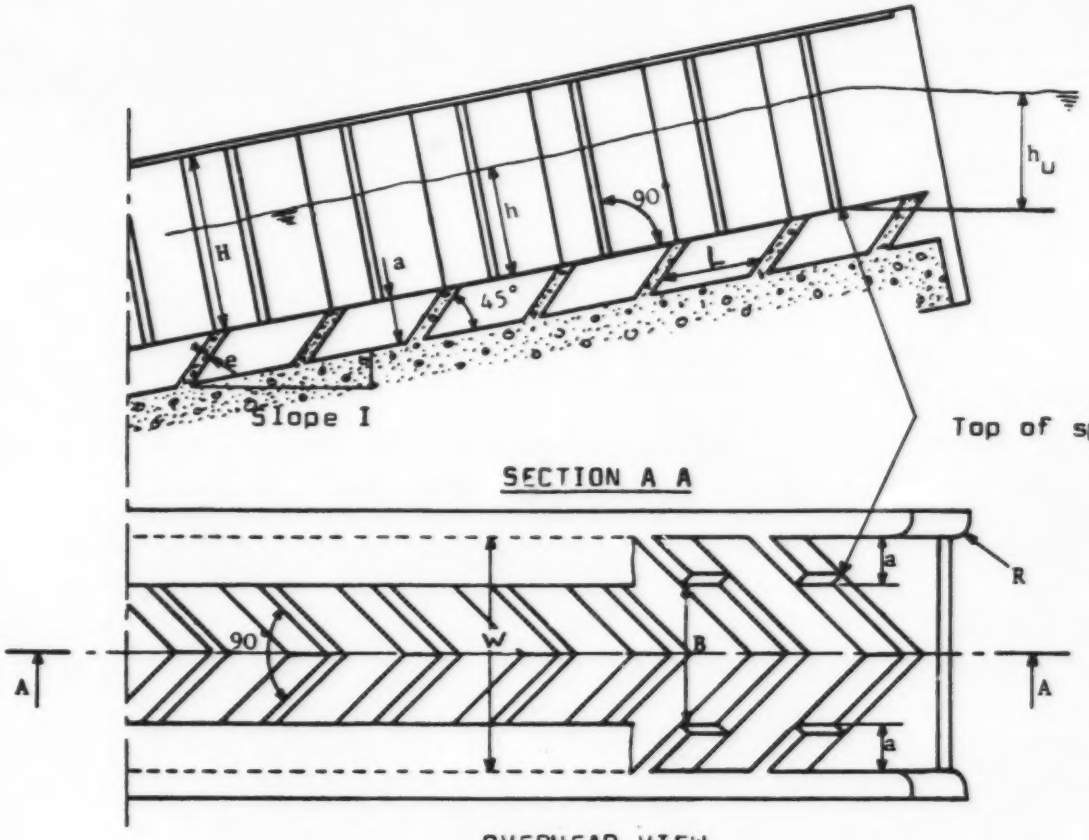
○ Velocity logging 6.75 cm away from centreline of fishway

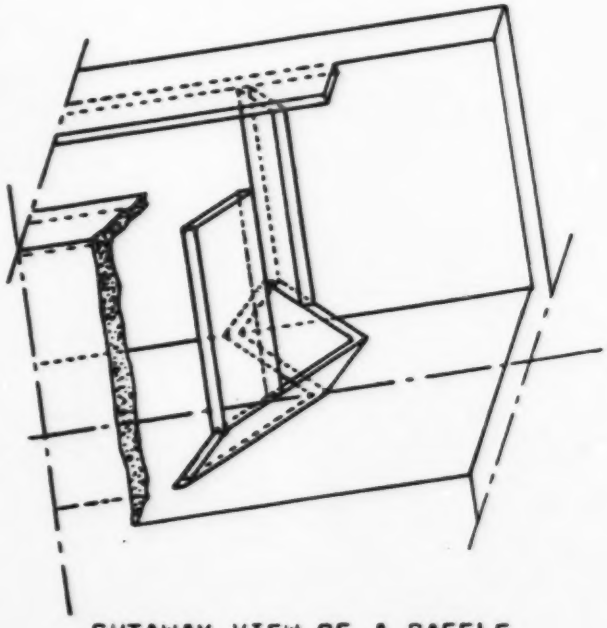


FISHWAY EQUIPPED WITH WING BAFFLES (width (W) = 30 cm)

Changes in velocity plotted against depth of flow

FISHWAY EQUIPPED WITH "FATOU" BAFFLES



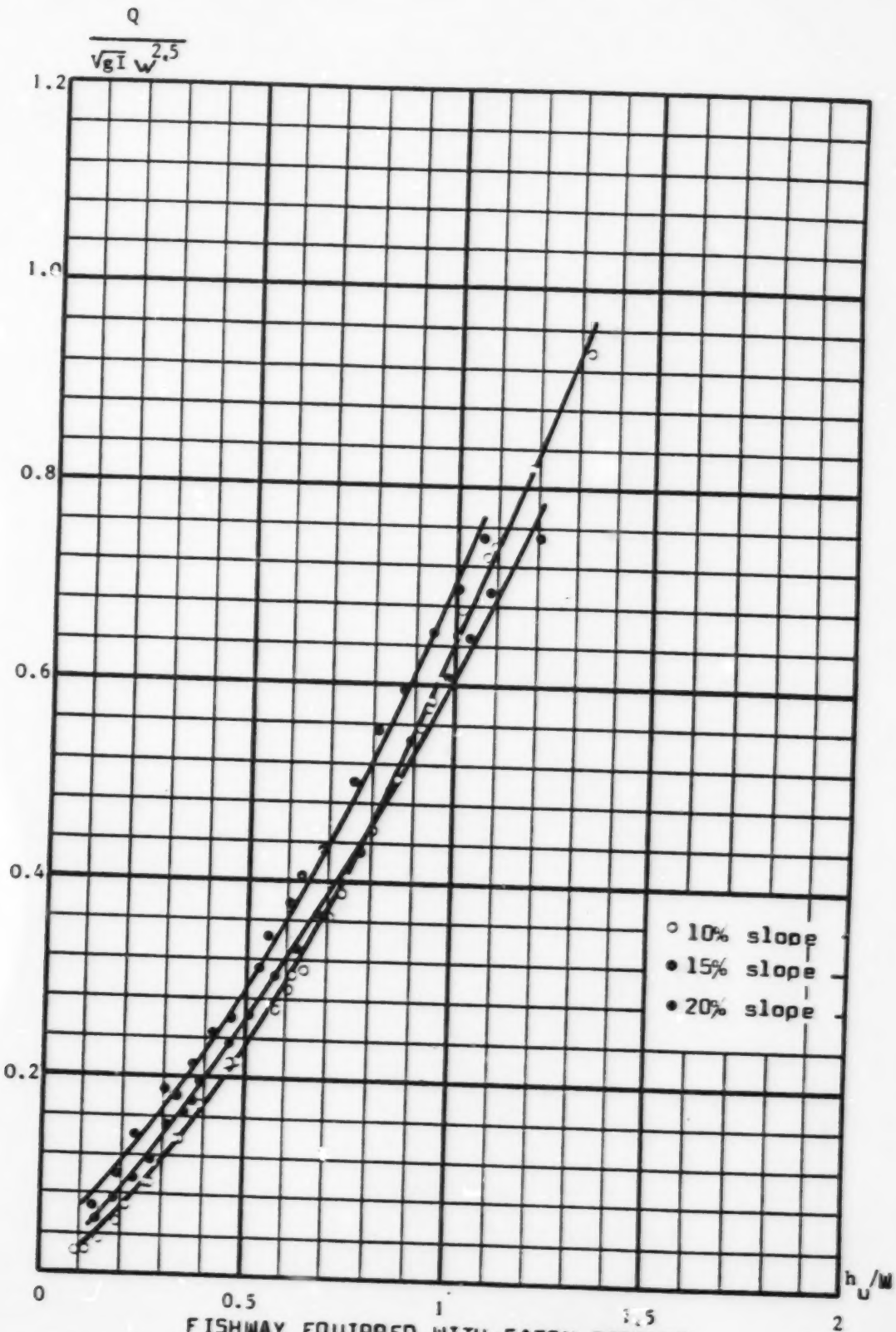


CUTAWAY VIEW OF A BAFFLE

B = 0,6 W
a = 0,2 W
P = 0,5 W
H = 1,333 W
R = 0,150 W
t = 1/30 W

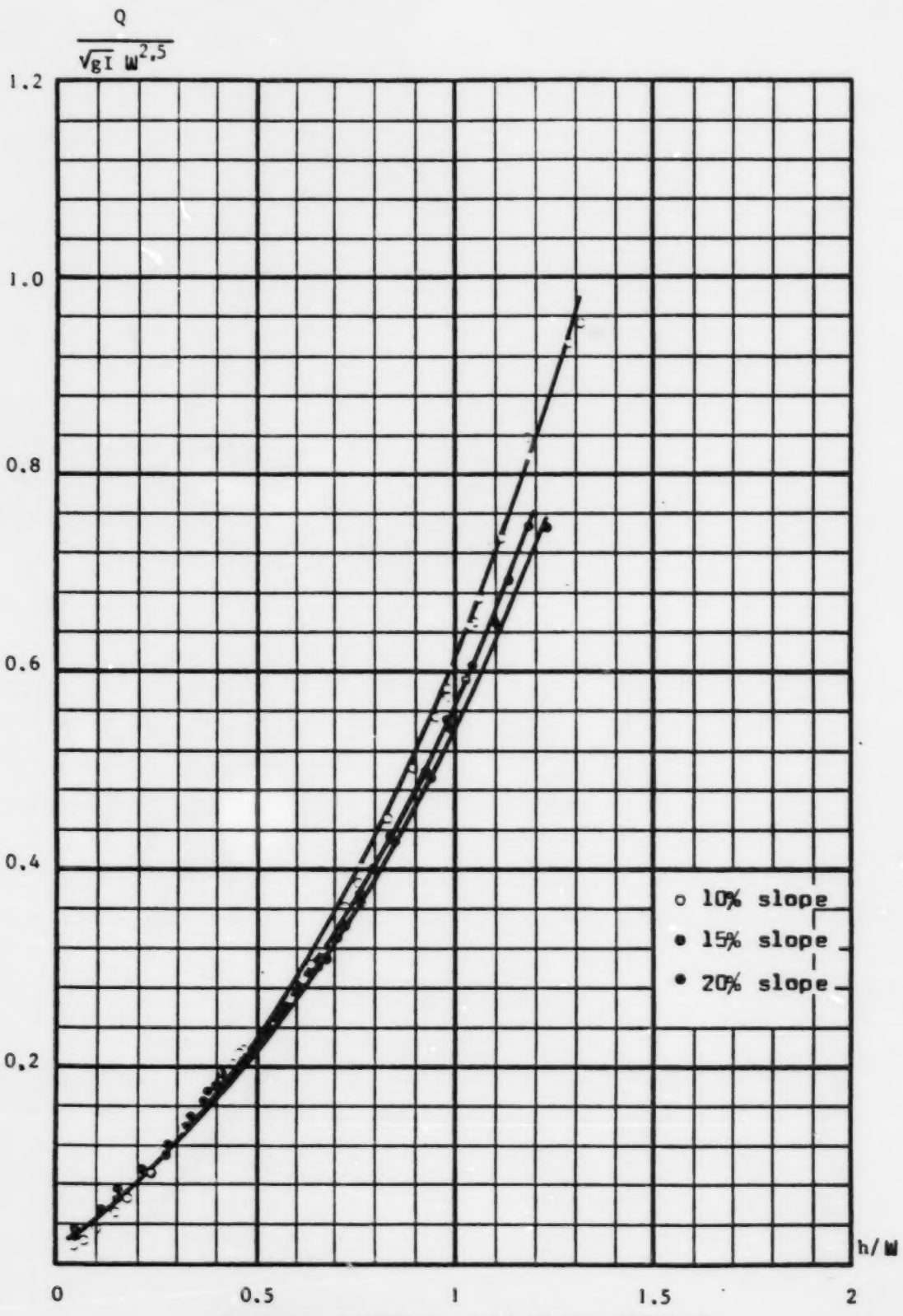
CHARACTERISTIC PARAMETERS OF A FISHWAY EQUIPPED WITH "FATOU" BAFFLES

(The lead-in conditions represented are the same as those used in the trials)



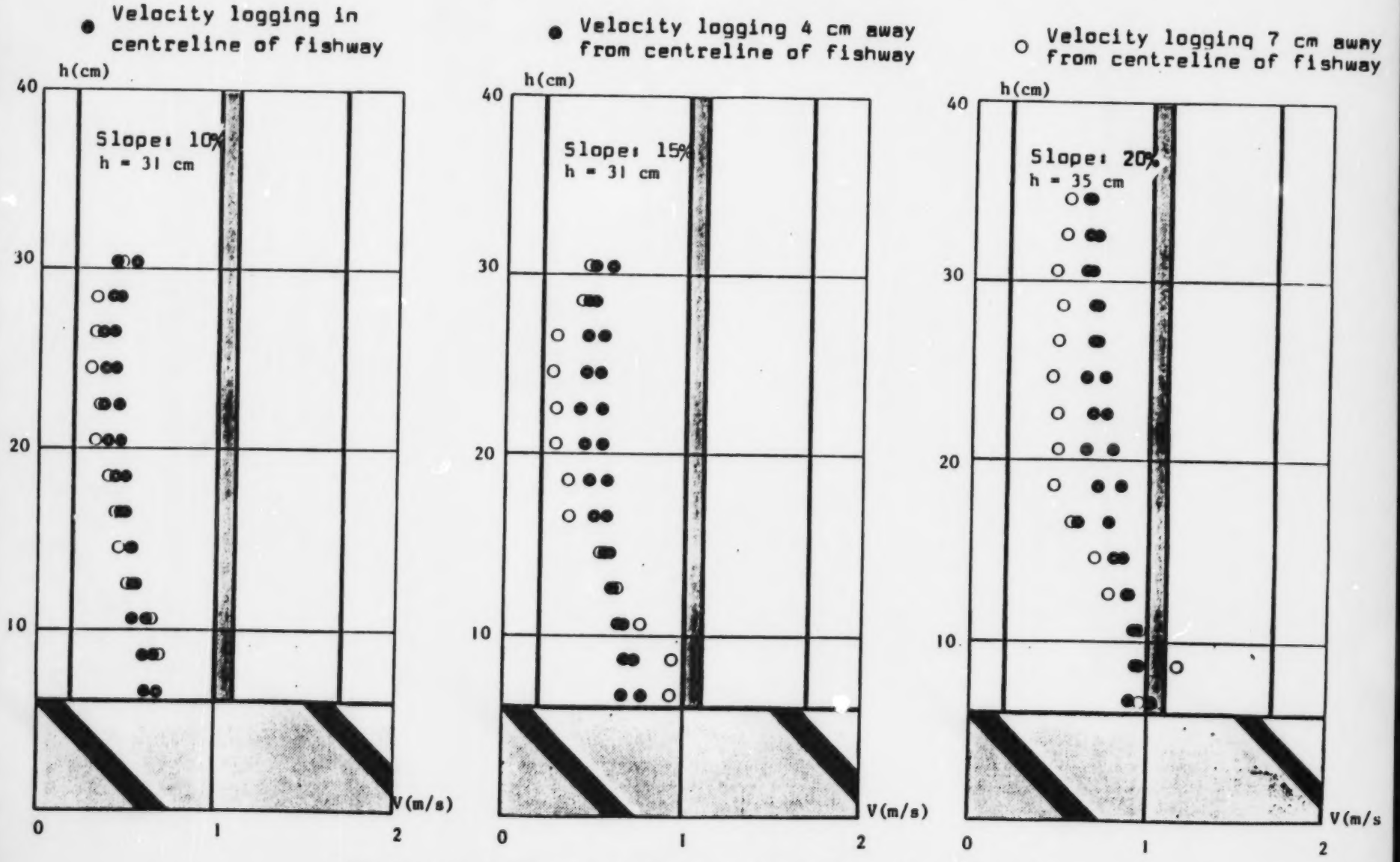
FISHWAY EQUIPPED WITH FATOU BAFFLES

Relationships among discharge, upstream load and slope



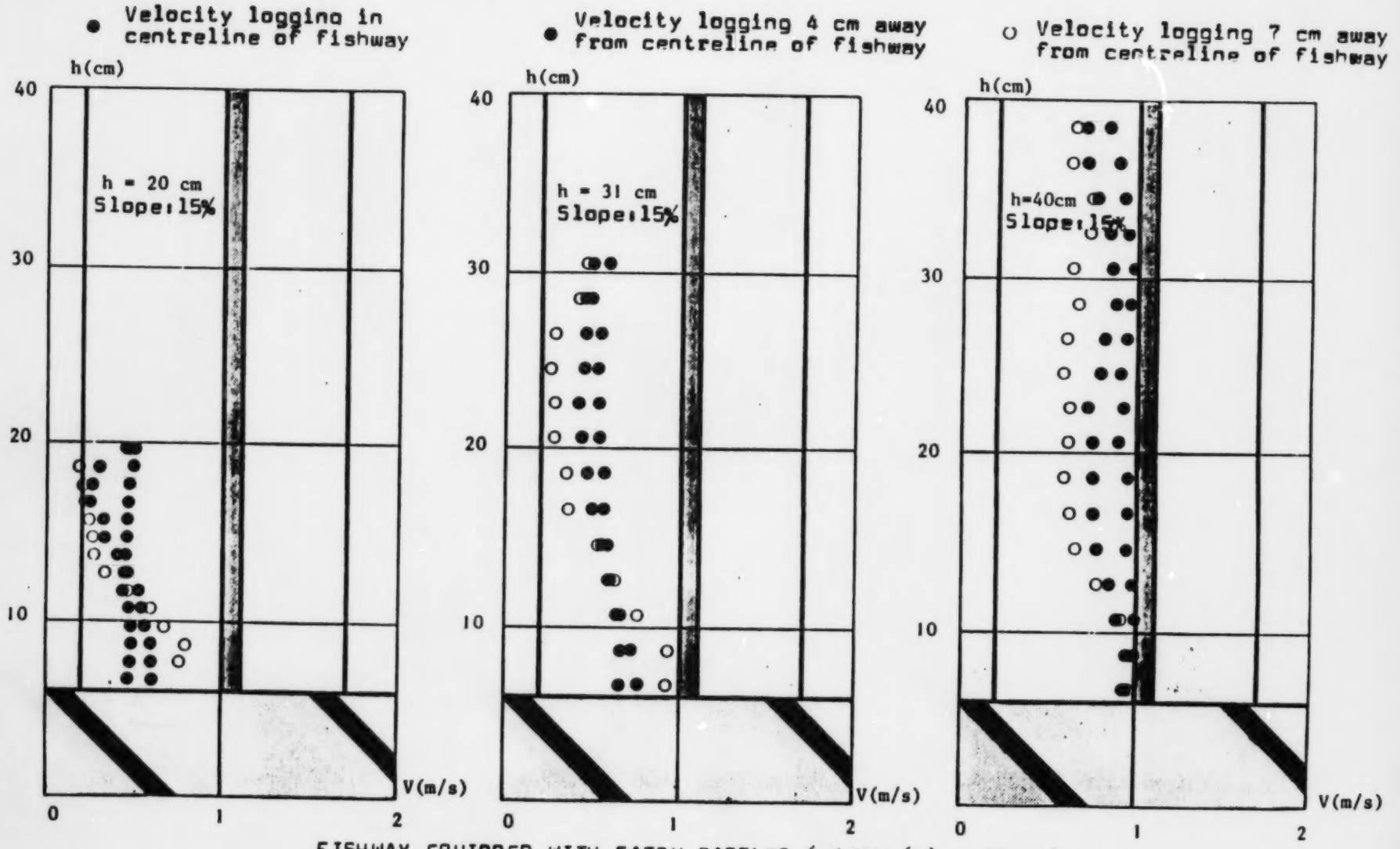
FISHWAY EQUIPPED WITh FATOU BAFFLES

Relationships among discharge, depth of flow and slope



FISHWAY EQUIPPED WITH FATOU BAFFLES (width (W) = 30 cm)

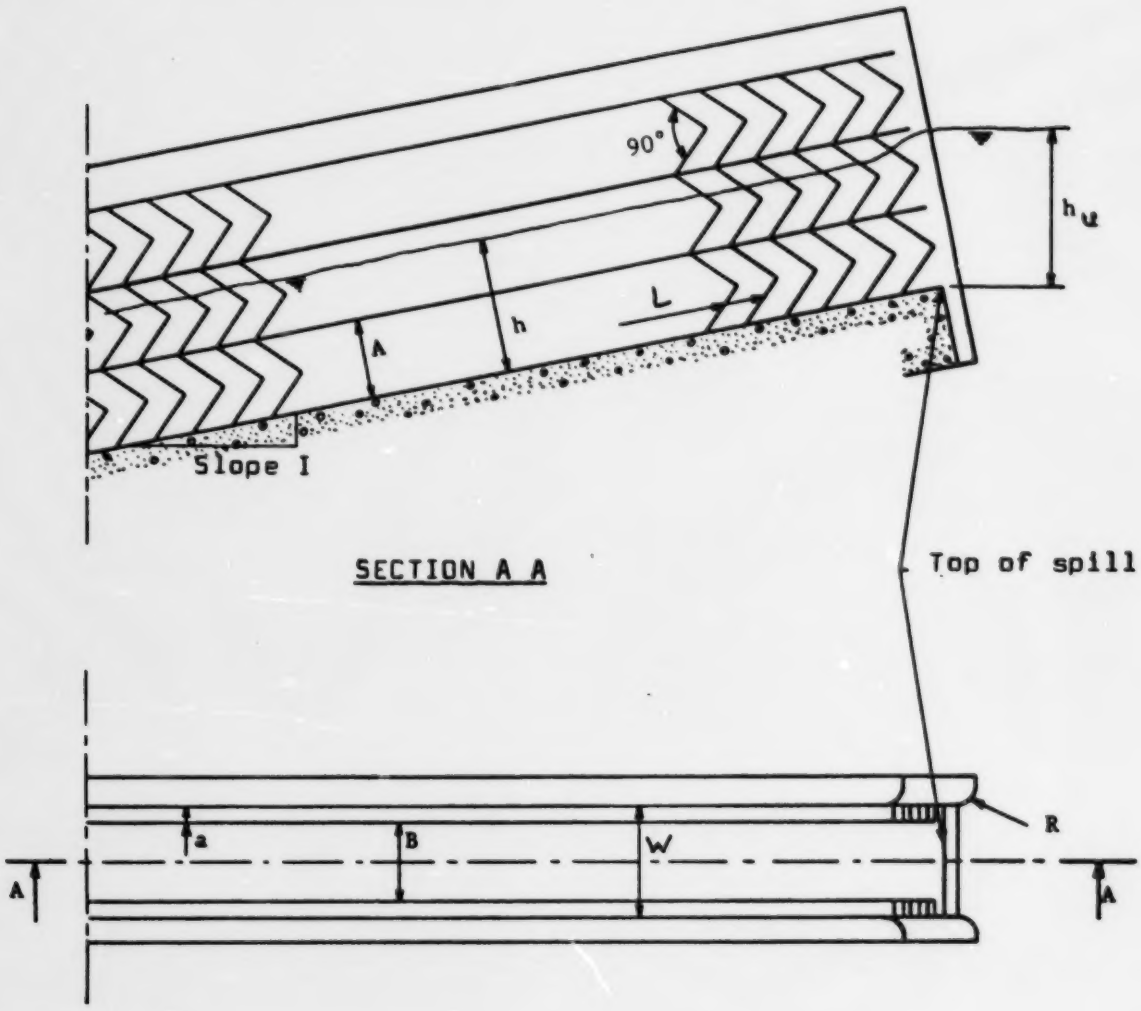
Changes in velocity plotted against slope



FISHWAY EQUIPPED WITH FATOU BAFFLES (width (W) = 30 cm)

Changes in velocity plotted against depth of flow

FISHWAY EQUIPPED WITH LATERAL V BAFFLES

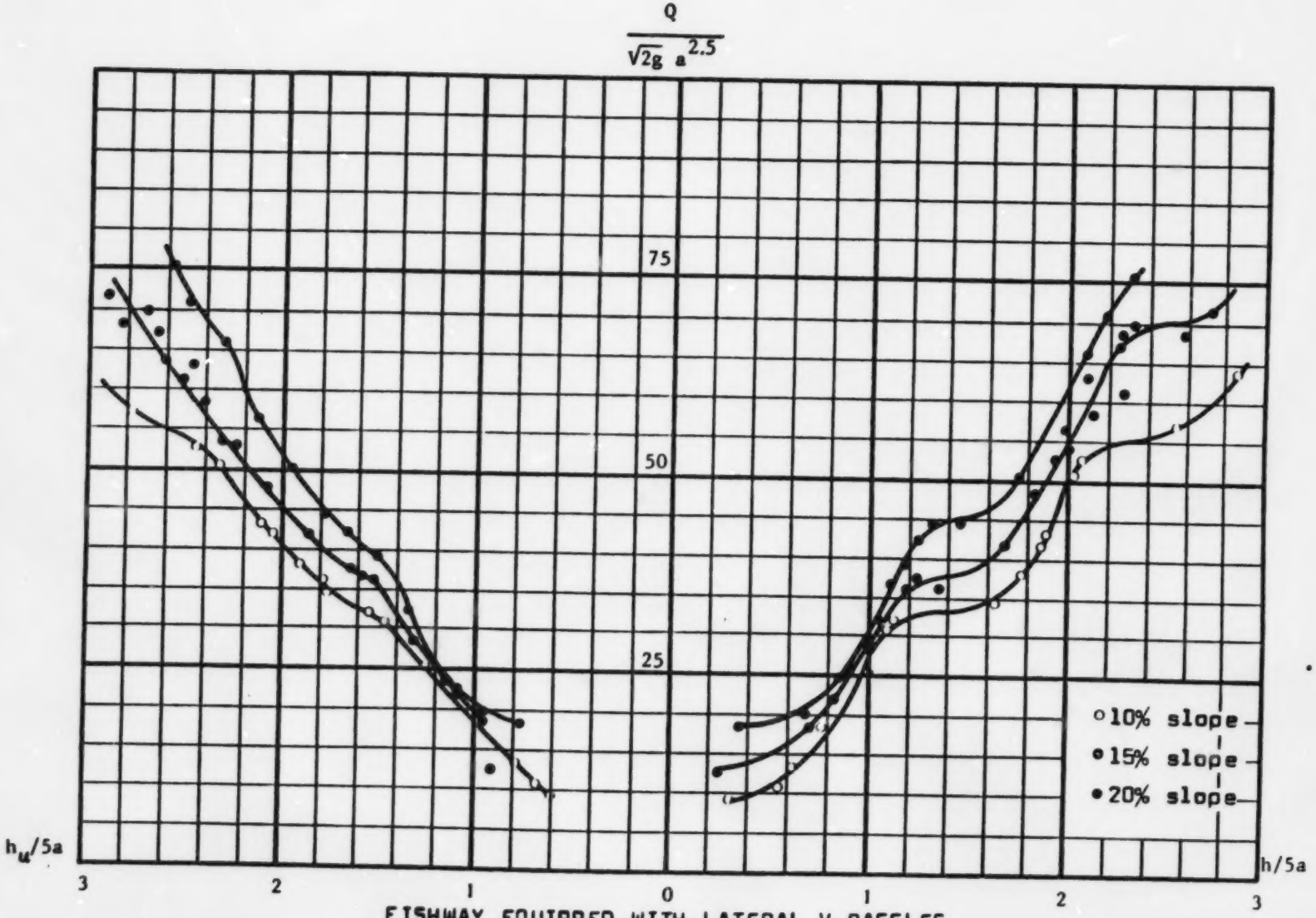


OVERHEAD VIEW

A = 5 a
B = 5 a
W = 7 a
L = 2.50 a
R = 1.50 a

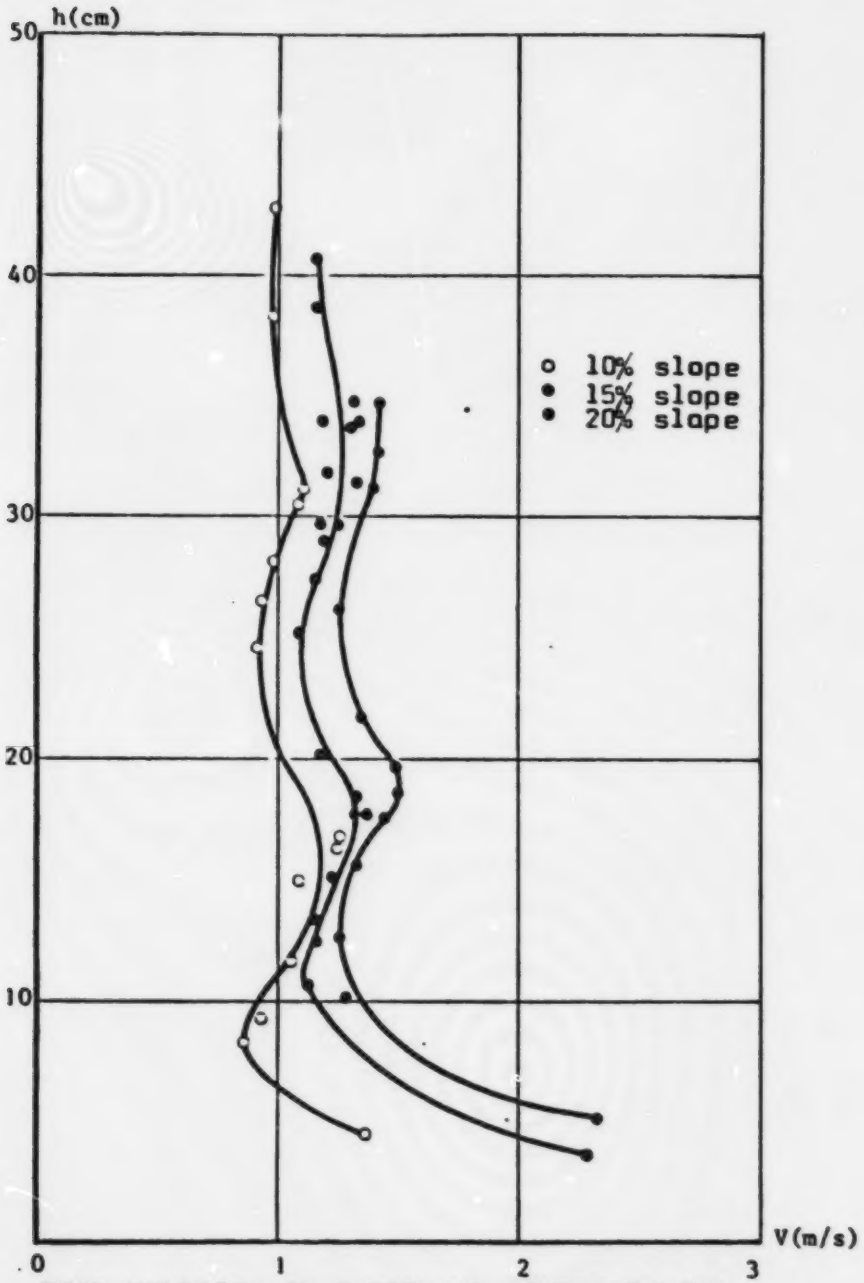
CHARACTERISTIC PARAMETERS OF A FISHWAY EQUIPPED WITH LATERAL V BAFFLES

(The lead-in conditions represented are the same as those used in the trials)

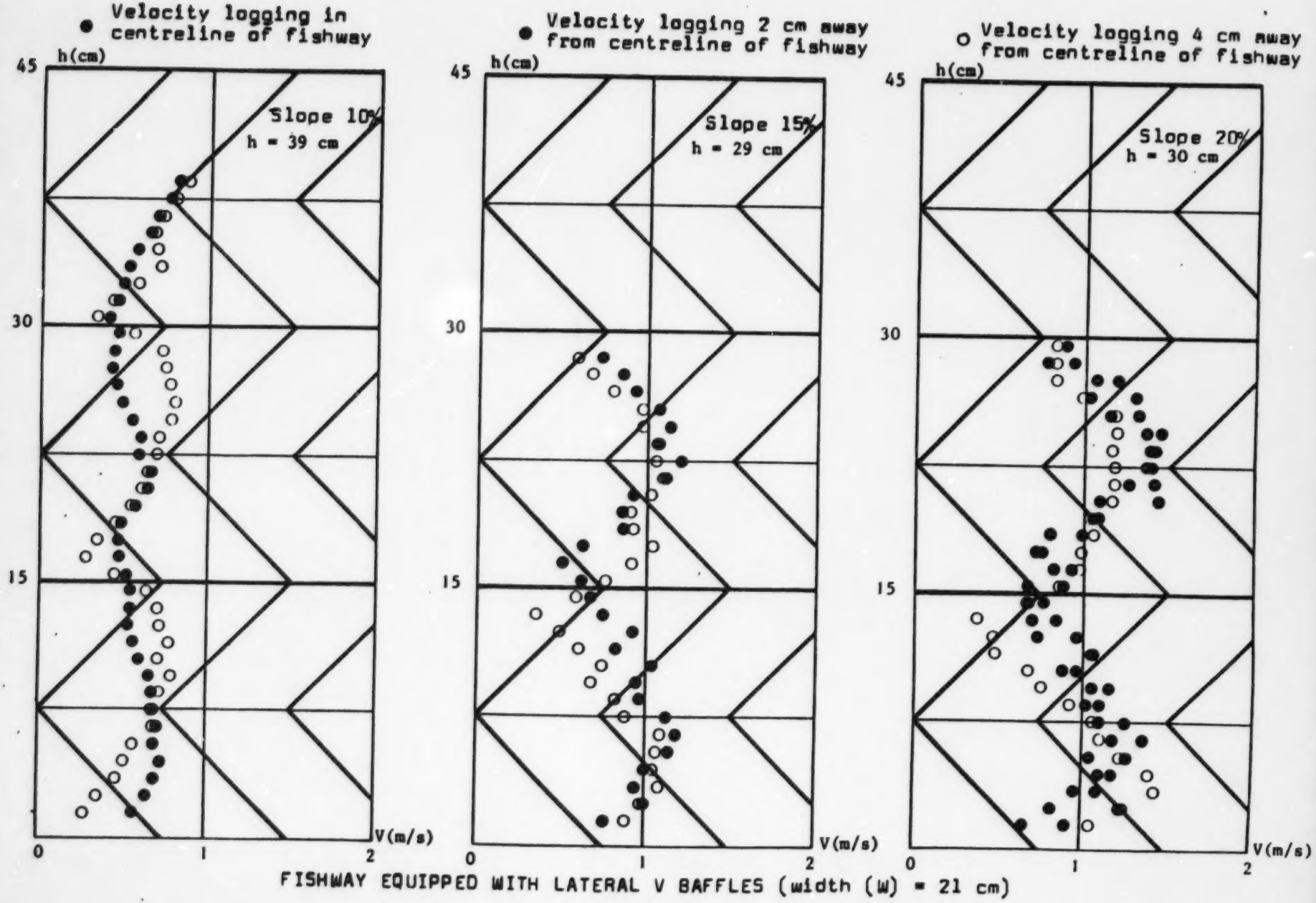


FISHWAY EQUIPPED WITH LATERAL V BAFFLES

Relationships among discharge, upstream load, depth of flow and slope



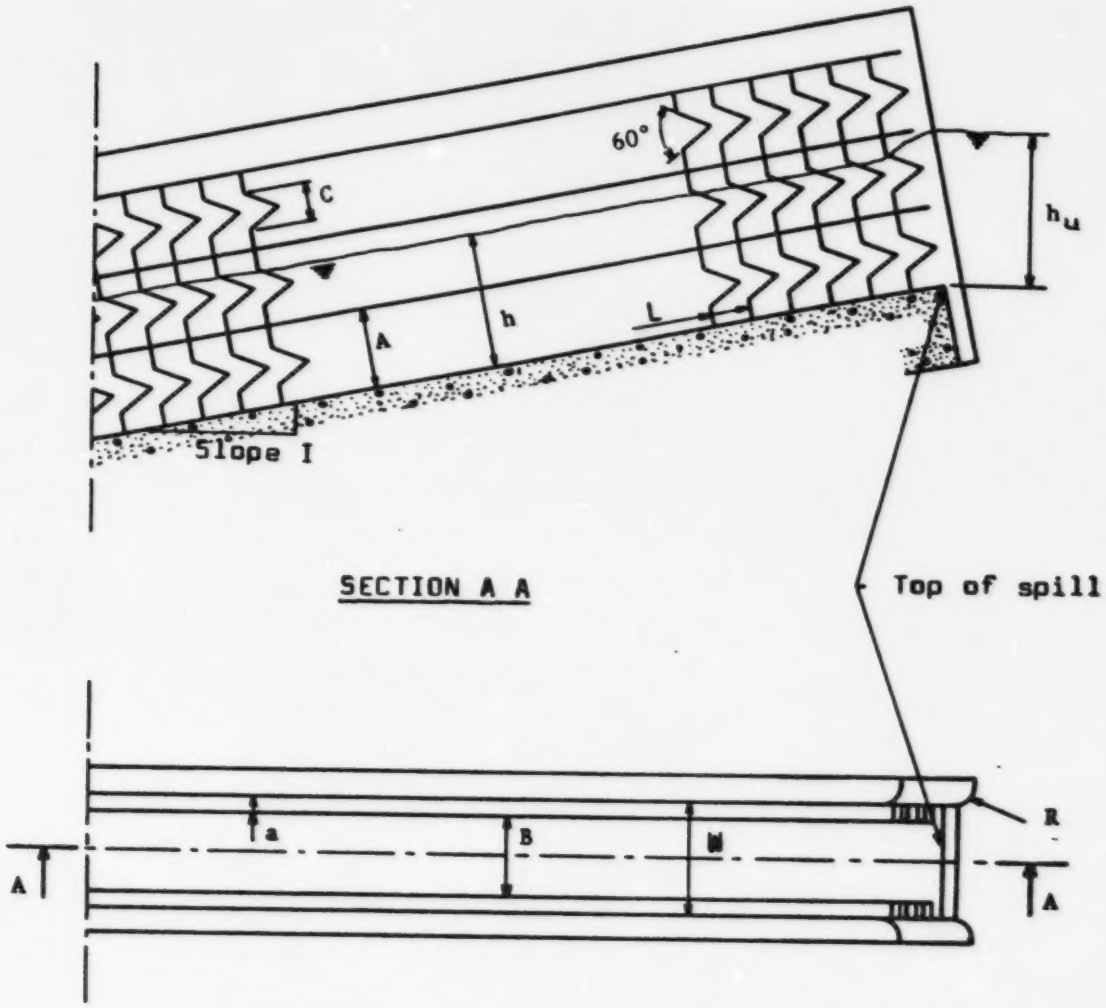
MEAN VELOCITY IN A FISHWAY EQUIPPED WITH LATERAL V BAFFLES PLOTTED AGAINST DEPTH OF FLOW



FISHWAY EQUIPPED WITH LATERAL V BAFFLES (width (W) = 21 cm)

Changes in velocity plotted against slope

FISHWAY EQUIPPED WITH TYPE A HIGH-ACTIVITY SIDE BAFFLES



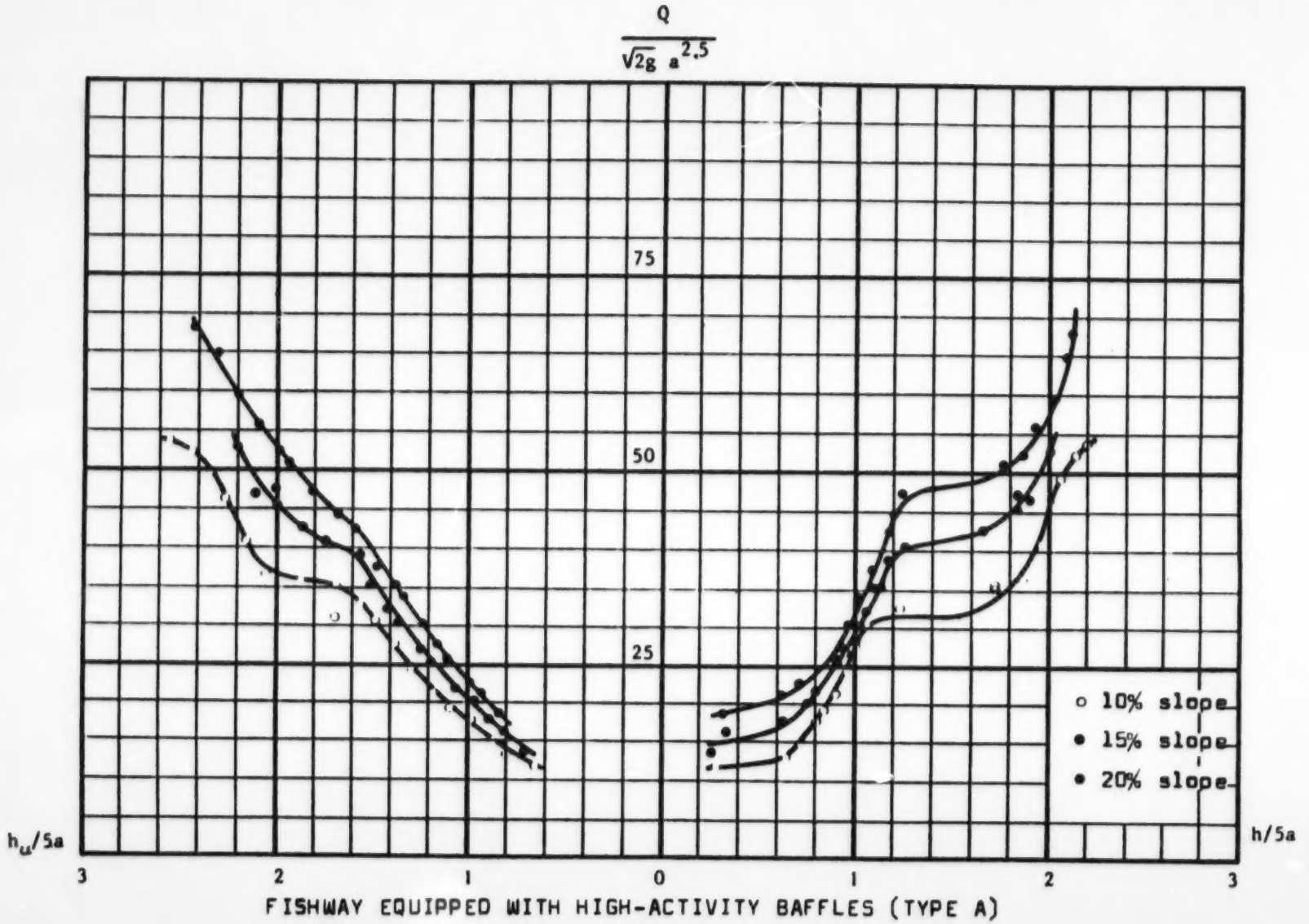
SECTION A A

OVERHEAD VIEW

A = 5 a	W = 7 a
B = 5 a	L = 2,50 a
C = 2,50 a	R = 1,50 a

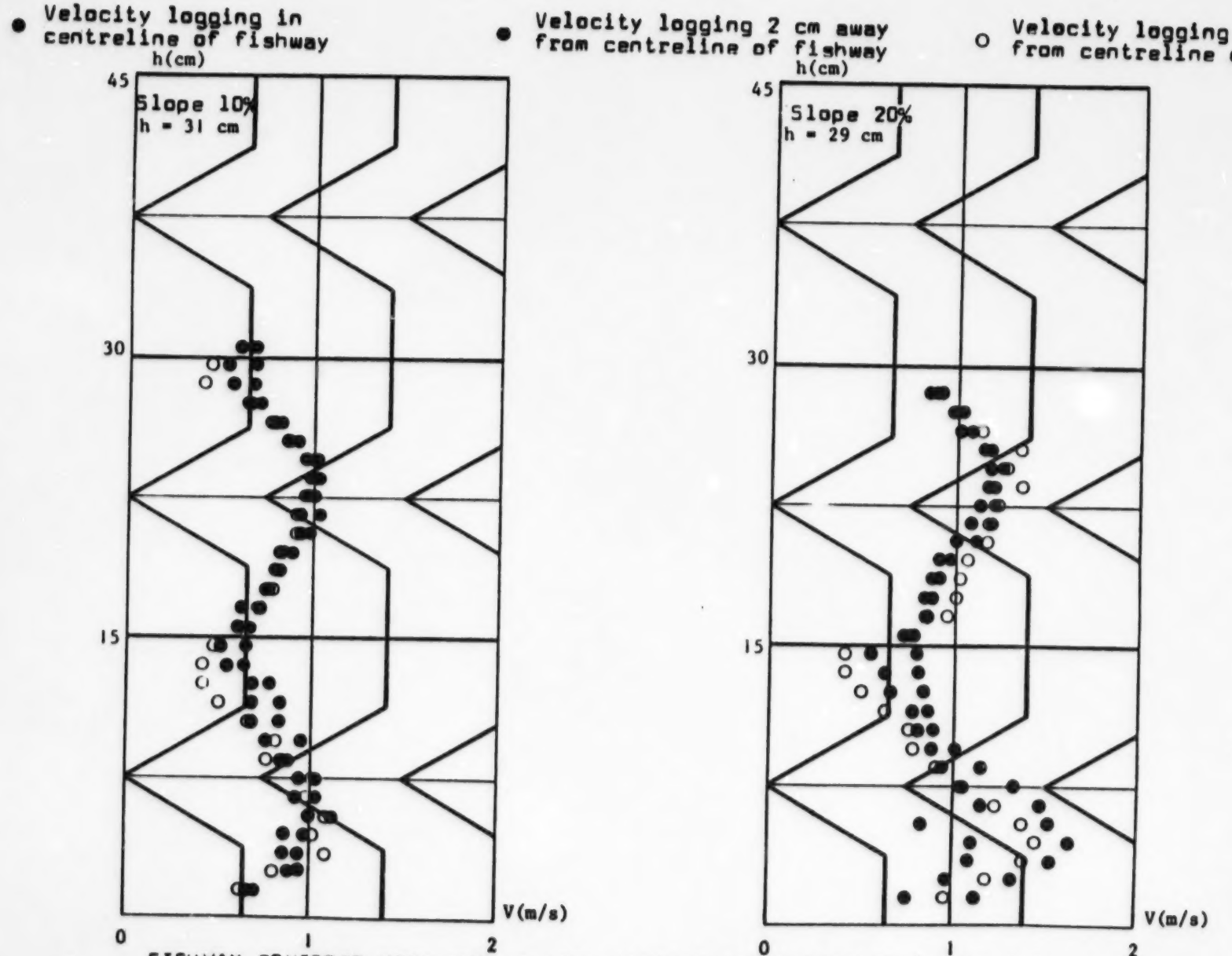
CHARACTERISTIC PARAMETERS OF A FISHWAY EQUIPPED WITH HIGH-ACTIVITY SIDE BAFFLES (TYPE A)

(The lead-in conditions represented are the same as those used in the trials)



FISHWAY EQUIPPED WITH HIGH-ACTIVITY BAFFLES (TYPE A)

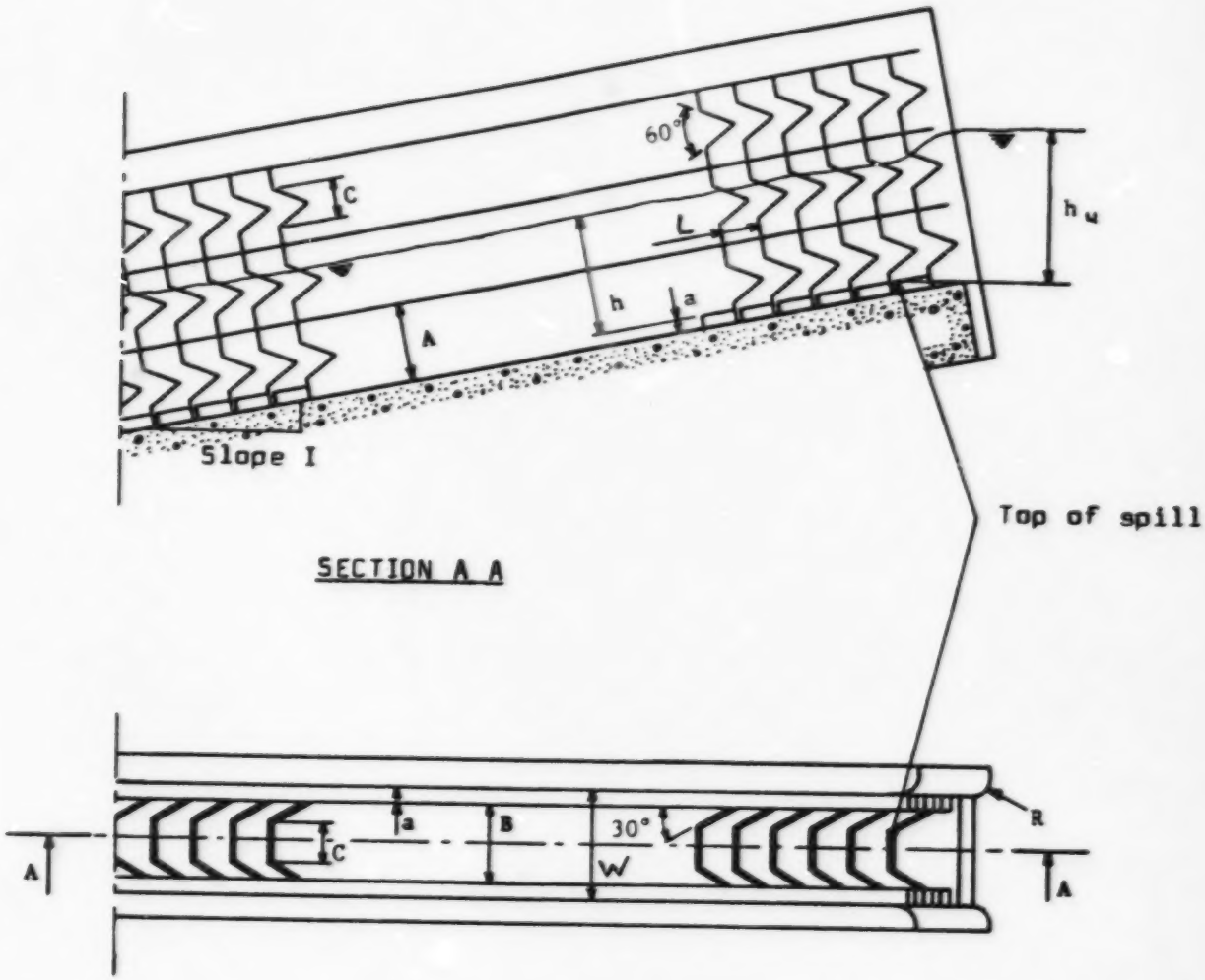
Relationships among discharge, depth of flow, upstream load and slope



FISHWAY EQUIPPED WITH TYPE A HIGH-ACTIVITY SIDE BAFFLES (width (W) = 21 cm)
Changes in velocity plotted against slope

FISHWAY EQUIPPED WITH TYPE A HIGH-ACTIVITY SIDE BAFFLES

ASSOCIATED WITH TYPE B HIGH-ACTIVITY BOTTOM BAFFLES



A = 5 a
B = 5 a
C = 2,50 a
W = 7 a
L = 2,50 a
R = 1,50 a

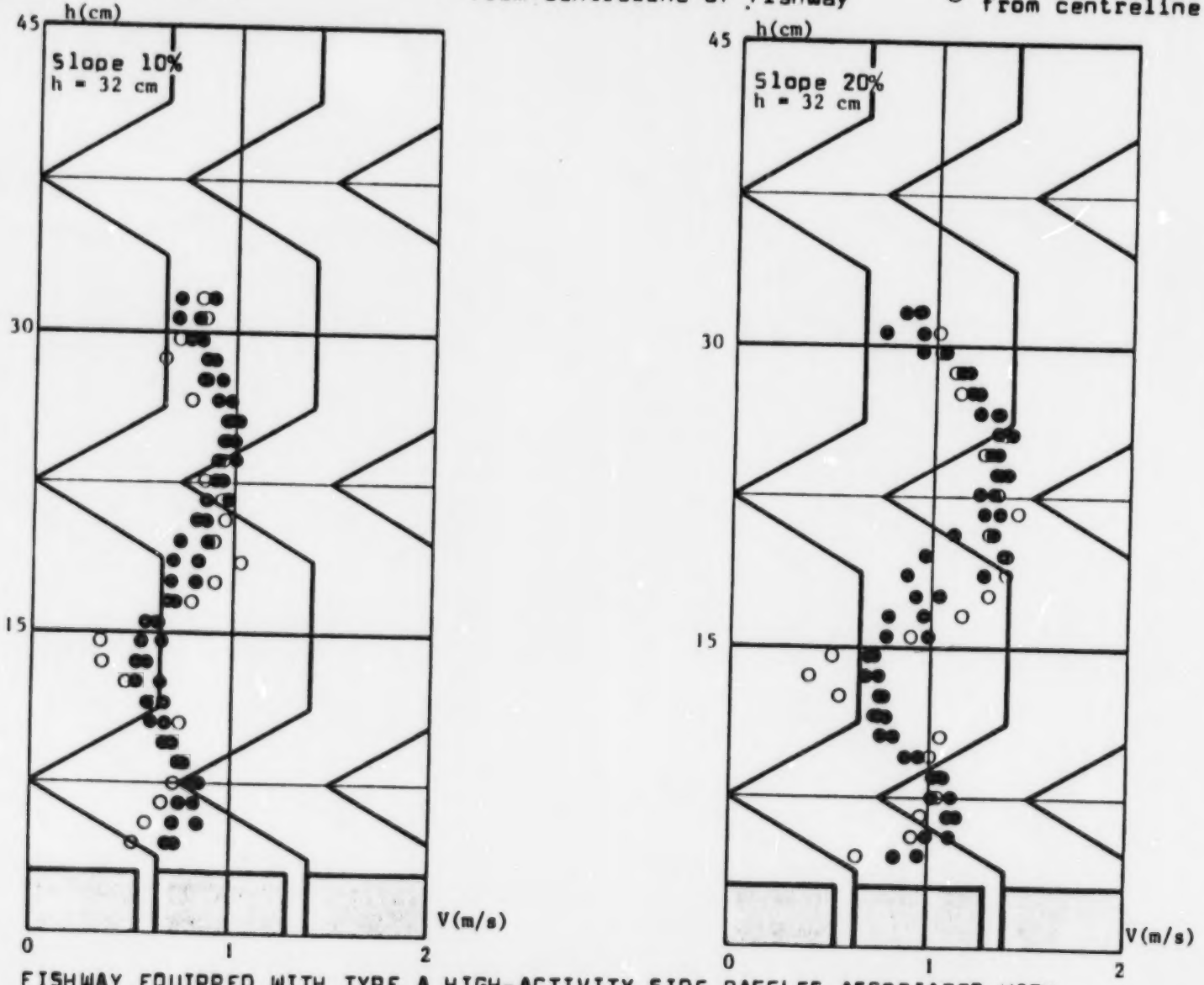
CHARACTERISTIC PARAMETERS OF A FISHWAY EQUIPPED WITH HIGH-ACTIVITY SIDE BAFFLES (TYPE A) ASSOCIATED WITH HIGH-ACTIVITY BOTTOM BAFFLES (TYPE B)

(The lead-in conditions represented are the same as those used in the trials)

● Velocity logging in centreline of fishway

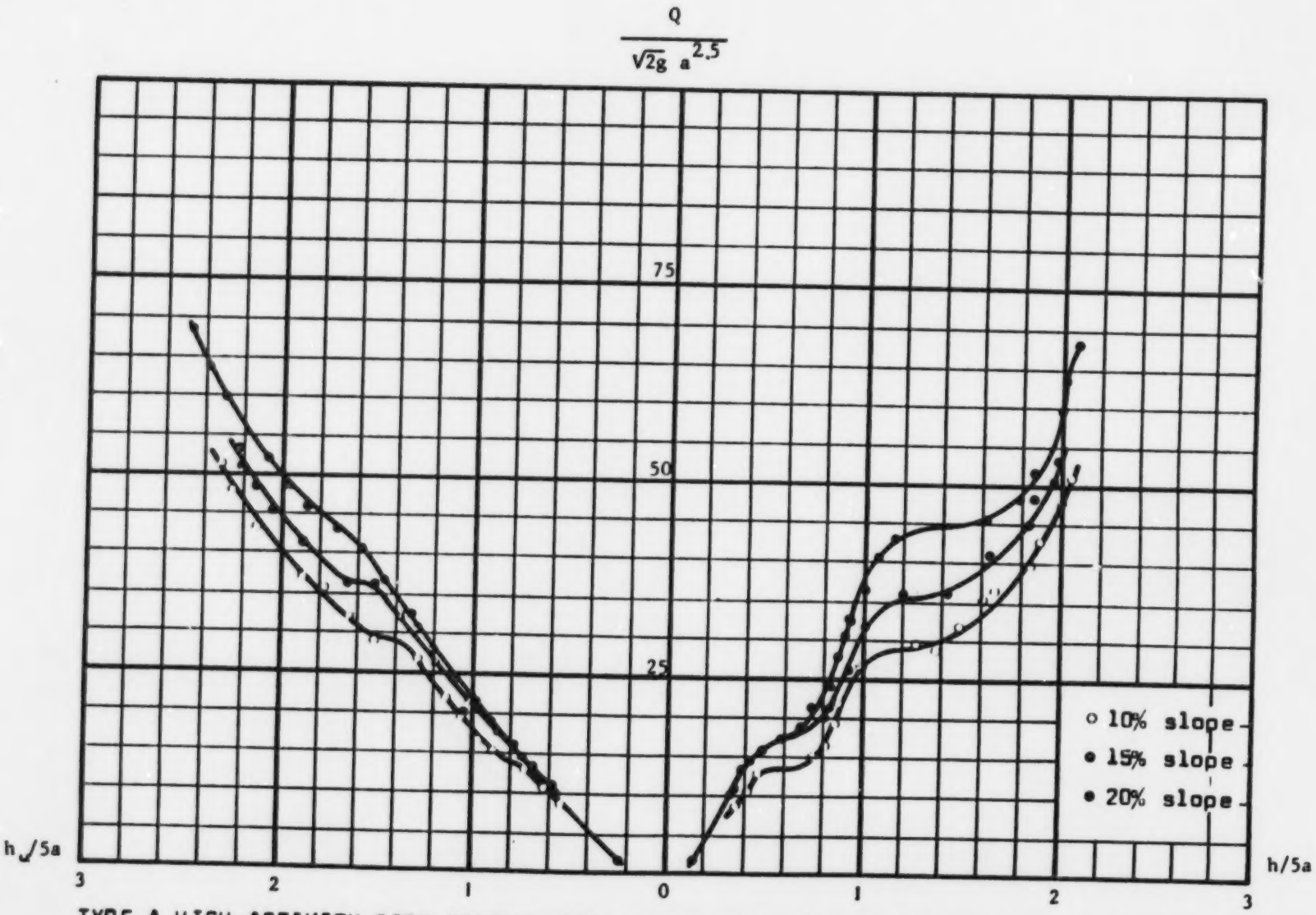
● Velocity logging 2 cm away from centreline of fishway

○ Velocity logging 4 cm away from centreline of fishway



FISHWAY EQUIPPED WITH TYPE A HIGH-ACTIVITY SIDE BAFFLES ASSOCIATED WITH TYPE B HIGH-ACTIVITY BOTTOM BAFFLES (width (W) = 21 cm)

Changes in velocity plotted against slope



TYPE A HIGH-ACTIVITY SIDE BAFFLES ASSOCIATED WITH TYPE B HIGH-ACTIVITY BOTTOM BAFFLES

Relationships among discharge, upstream load, depth of flow and slope